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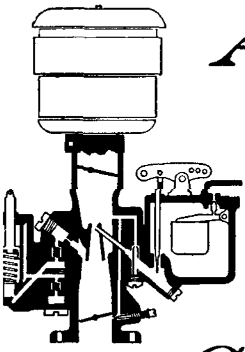

AUTOMOTIVE Fuel, Lubricating and Cooling Systems

Construction, Operation, and Maintenance

SECOND EDITION

William H. Crouse

McGRAW-HILL BOOK COMPANY, INC.
New York Chicago San Francisco Dallas Toronto London

ABOUT THE AUTHOR

Behind William H. Crouse's clear technical writing is a background of sound mechanical engineering training as well as a variety of practical industrial experiences. He spent a year after finishing high school working in a tinplate mill, summers, while still in school, working in General Motors plants, and three years working in the Delco-Remy Division shops. Later he became Director of Field Education in the Delco-Remy Division of General Motors Corporation, which gave him an opportunity to develop and use his natural writing talent in the preparation of service bulletins and educational literature.

During the war years, he wrote a number of technical manuals for the Armed Forces. After the war, he became Editor of Technical Education Books for the McGraw-Hill Book Company. He has contributed numerous articles to automotive and engineering magazines and has written several outstanding books: *Automotive Mechanics, Electrical Appliance Servicing, Everyday Automobile Repairs, Everyday Household Appliance Repairs,* and *Understanding Science.*

William H. Crouse's outstanding work in the automotive field has earned for him membership in the Society of Automotive Engineers and in the American Society for Engineering Education.

AUTOMOTIVE FUEL, LUBRICATING, AND COOLING SYSTEMS

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How to study this book

THIS IS one of a series of five books covering in detail the construction, operation, and maintenance of automobiles. The five books are designed to give you the complete background of information you need to become an automotive mechanic. Furthermore, the comprehensive coverage of the subject matter in the books should make them a valuable addition to the library of anyone interested in any phase of automobile engineering, manufacturing, sales, service, and operation.

GETTING PRACTICAL EXPERIENCE

Of course, these books alone will not make you an automotive mechanic, just as books alone do not make an airplane pilot or a dentist or an architect the expert he is. Practice also is required, practice in handling automotive parts and automotive tools and in following automotive servicing procedures. The books will give you the theoretical background you need, but you should seek out means of getting practice, also. If you are taking a regular course in automotive mechanics, you will get practical experience in the school automotive shop. But if you are not taking a regular course in a school, you may still be able to make use of the facilities of any nearby school with an automotive shop. Perhaps you will meet others who are taking an automotive mechanics course and can talk over any problems you have. This often clears up difficult points. A local garage or service station is a good source of practical information. If you can get acquainted with the automotive mechanics there, so much the better. Watch them as they work; notice how they do things. Then go home and think about it. Perhaps the mechanics will allow you to handle various parts and possibly even help with some of the servicing jobs.

SERVICE PUBLICATIONS

While you are in the service shop, try to get a chance to study the various publications they receive. Automobile manufacturers, as well as suppliers of parts, accessories, and tools, publish shop manuals, service bulletins, and parts catalogues. All these are designed to help service personnel do a better job. In addition, numerous automotive magazines are published which deal with the problems and methods of automotive service. All these publications will be of great value to you; study them carefully.

These various activities will help you gain practical experience in automotive mechanics. Sooner or later this experience, plus the knowledge that you have gained in reading the five books in the McGraw-Hill Automotive Mechanics Series, will permit you to step into the automotive shop on a full-time basis. Or, if you are already in the shop, you will be equipped to step up to a better and a more responsible job.

CHECKING UP ON YOURSELF

Every few pages in the book you are given the chance to check the progress you are making by answering a series of questions. You will notice that there are two types of tests, *progress quizzes* and *chapter checkups*. Each progress quiz should be taken just after you have completed the pages preceding it. The quizzes allow you to check yourself quickly as you finish a lesson. On the other hand, the chapter checkups may cover several lessons, since they are review tests of entire chapters. Since they are review tests, you should review the entire chapter by rereading it or at least paging through it to check important points before trying the test. If any of the questions stump you, reread the pages in the book that will give you the answer. This sort of review is very valuable and will help you fix in your mind the essential information you will need when you go into the automotive shop. Do not write in the book. Instead, write down your answers in a notebook.

KEEPING A NOTEBOOK

Most of the questions require a written answer. It would be well for you to keep a notebook and write the answers in the notebook.

Also, you can write down in the notebook important facts that you pick up from reading the book or from working in the shop. As you do this, you will find that the notebook will become a valuable source of information to which you can refer. Use a loose-leaf, ring-binder type of notebook so that you can insert or remove pages and thereby add to and improve your notebook.

GLOSSARY AND INDEX

There is a list of automotive terms in the back of the book, along with their definitions. Whenever you have any doubt about the meaning of some term or about what purpose some automotive part has, you can refer to this list, or Glossary. Also, in the back of the book you will find an Index. This Index will help you look up anything in the book that you are not sure about. For example, if you wanted to refresh your mind on how some component works, you could find it quickly by looking in the Index to find what pages the information is on.

AUTOMOTIVE TOOLS AND COMPONENTS

In the *Automotive Engines* book (one of the five books in the McGraw-Hill Automotive Mechanics Series) there is a chapter on automotive tools. This chapter is an important one and should be studied along with any of the books in the McGraw-Hill Automotive Mechanics Series. In other words, the information in the chapter on tools applies to all service operations on the car, and not just to engine service. The *Automotive Engines* book also has a chapter on automotive components that describes briefly the operation of all the mechanisms in the automobile. Reference should be made to this chapter if the reader desires a short explanation of any component.

And now, good luck to you. You are engaged in the study of a fascinating, complex, and admirable mechanism—the automobile. Your studies can lead you to success in the automotive field, a field where opportunities are great. For it is the man who knows—the man who can do things—who moves ahead. Let this man be you.

WILLIAM H. CROUSE

Preface to the second edition

RAPID technological developments in the automotive field, as well as advancements in educational methods required to keep pace with these new developments, have made advisable a new edition of *Automotive Fuel, Lubricating, and Cooling Systems.* This revision includes material on the new automotive equipment introduced in the past three years and related servicing techniques. Insofar as possible, this new material has not been appended to the old; instead, it has been integrated into the pattern of the text so that the student sees the new material as part of the complete presentation.

The comments and suggestions of teachers and students who have used the earlier edition have been carefully analyzed and acted upon where possible during the revision of the text. Reports of their experience in the actual use of the text for classroom and home study have been of paramount importance to the author in his efforts to make the book of maximum usefulness. Improvements that have been made in the present edition, therefore, should be credited to these users, and acknowledgment of their helpful suggestions is herewith gratefully extended.

WILLIAM H. CROUSE

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Acknowledgments

DURING the several years that the five books in the McGraw-Hill Automotive Mechanics Series (of which this is one) were in preparation, the author was given invaluable aid and inspiration by many, many people in the automotive industry and in the field of education. The author gratefully acknowledges his indebtedness and offers his sincere thanks to these many people. All cooperated with the aim of providing accurate and complete information that would be useful in the training of automotive mechanics. Special thanks are due to the following organizations for information and illustrations that they supplied: AC Spark Plug Division, Buick Motor Division, Cadillac Motor Car Division, Chevrolet Motor Division, Delco Products Division, Delco-Remy Division, Detroit Diesel Engine Division, Frigidaire Division, Oldsmobile Division, Pontiac Motor Division, Saginaw Steering Gear Division, and United Motors Service Division of General Motors Corporation; Allen Electric and Equipment Company; American Exporter's Automotive World; Akron Equipment Company; American Motors Corporation; Barrett Equipment Company; Bear Manufacturing Company; Bendix Products Division of Bendix Aviation Corporation; Black and Decker Manufacturing Company; Carter Carburetor Company; Chrysler Sales Division, De Soto Division, Dodge Division, and Plymouth Division of Chrysler Corporation; Clayton Manufacturing Company; Henry Disston and Sons, Inc.; Eaton Manufacturing Company; E. I. du Pont de Nemours & Company, Inc.; Electric Auto-Lite Company; Federal-Mogul Corporation; E. Edelmann and Company; Federal Motor Truck Company; Ford Motor Company; Gemmer Manufacturing Company; B. F. Goodrich Company; Greenfield Tap and Die Corporation; Hall Manufacturing Company; Jam Handy Organization, Inc.; Hercules Motors Corporation; Hobart Brothers; Hotpoint, Inc.; Houde Engineering Division of Houdaille-Hershey Corporation; International Harvester Company; Kaiser Motors Corporation; K-D Manufacturing Company; Kelsey-Hayes Wheel Company; Kent-Moor Organization, Inc.; Johnson Bronze Company; King-Seeley Corporation; Lincoln-Mercury Division of Ford Motor Company; Linde Air Products Company; Mack-International

Motor Truck Corporation; Metalizing Company of America; Alexander Milburn Company; Monmouth Products Company; Monroe Auto Equipment Company; Muskegon Piston Ring Company; New Britain Machine Company; North American Electric Lamp Company; Perfect Circle Company; Ramsey Accessories Manufacturing Company; Rottler Boring Bar Company; A. Schrader's Son Division of Scovill Manufacturing Company, Inc.; Sealed Power Corporation; South Bend Lathe Works; Spicer Manufacturing Corporation; Standard Oil Company; Storm Manufacturing Company, Inc.; Studebaker-Packard Corporation; Sun Electric Corporation; Sunnen Products Company; Thompson Products Inc.; United Specialties Company; United States Rubber Company; Van Norman Company; Warner Electric Brake Manufacturing Company; Waukesha Motor Company; Weaver Manufacturing Company; Wilkening Manufacturing Company; and Zenith Carburetor Company.

Special thanks are also due to the staff and instructors at General Motors Institute; they supplied the author with much excellent information and gave him great assistance during certain phases of the work on the McGraw-Hill Automotive Mechanics Series. To all these organizations and the people who represent them, sincere thanks!

WILLIAM H. CROUSE

1: Automotive fundamentals

THIS CHAPTER discusses engine operation. It supplies you with the background information you need to understand the operation of the fuel, lubricating, and cooling systems.

§1. Purpose of this book You have shown your interest in automotive engines by starting to read this book. We hope to maintain your interest by giving you, in the pages of this book, a great deal of information on engine fuel, cooling, and lubricating systems. Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) describes in detail engine construction, operation, and service. This book covers the fuel, cooling, and lubricating systems used on automotive engines and supplies details of their construction, operation, and service. Regardless of what job you have or hope to have in the future in the automotive field, the information in this book should prove of value to you. The automotive mechanic, the automotive engineer, the man working at the higher level in automotive manufacture, sales, service, or operation should be able to do his job better if he has the information in this book at his finger tips. And naturally, this information will equip him for the bigger job ahead. The man who knows the facts and can use them in a practical way is the man who forges ahead in his chosen field. This book is designed to help you be that man.

§2. Components of the automobile Before we begin our studies of the fuel, lubricating, and cooling systems, let us first take a quick look at the complete automobile and the automobile engine. The automobile might be said to consist of five basic mechanisms, or components. These are:

1. The engine, which is the source of power and which includes the fuel, lubricating, cooling, and electric systems.

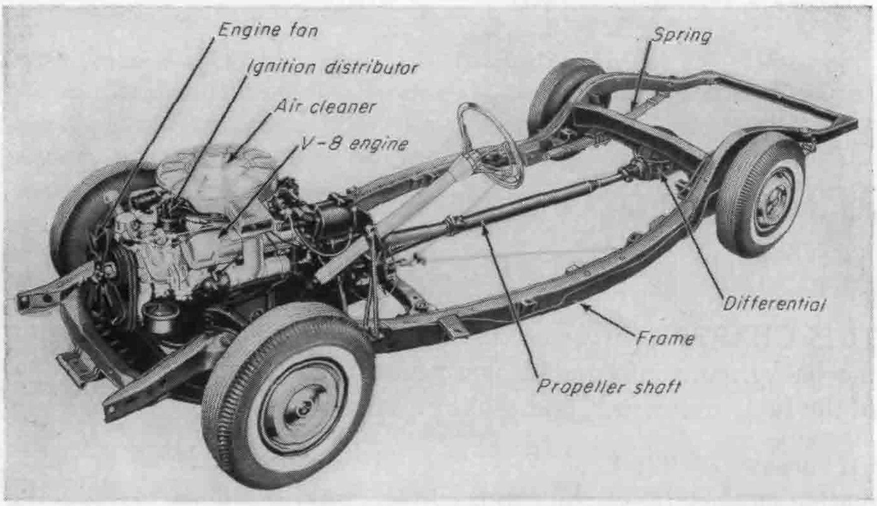


FIG. 1-1. Chassis of a passenger car. (*Mercury Division of Ford Motor Company*)

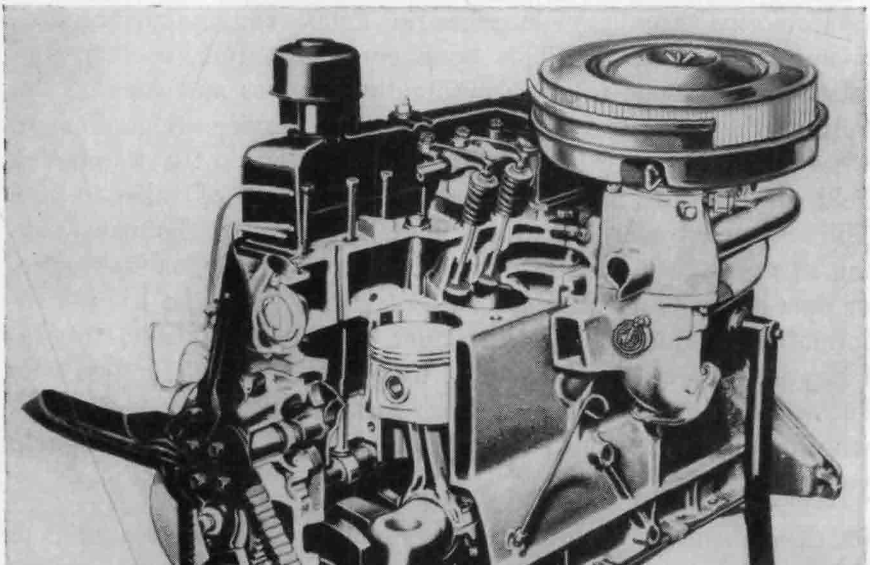


FIG. 1-2. A typical six-cylinder engine partly cut away to show the internal construction. (*Ford Division of Ford Motor Company*)

2. The frame, which supports the engine, wheels, steering and braking systems, and body.
3. The power train, which carries the power from the engine (through the clutch, transmission, propeller shaft, differential, and axles) to the car wheels.
4. The car body.
5. Car-body accessories, including heater, lights, windshield wipers, and so forth.

Figure 1-1 illustrates the chassis of an automobile. The chassis is made up of the frame, engine, power train, wheels, and steering and braking systems.

§3. The engine The engine (Fig. 1-2) is the source of power that makes the wheels turn and the car move. It is usually called an *internal-combustion engine* because gasoline is burned inside the

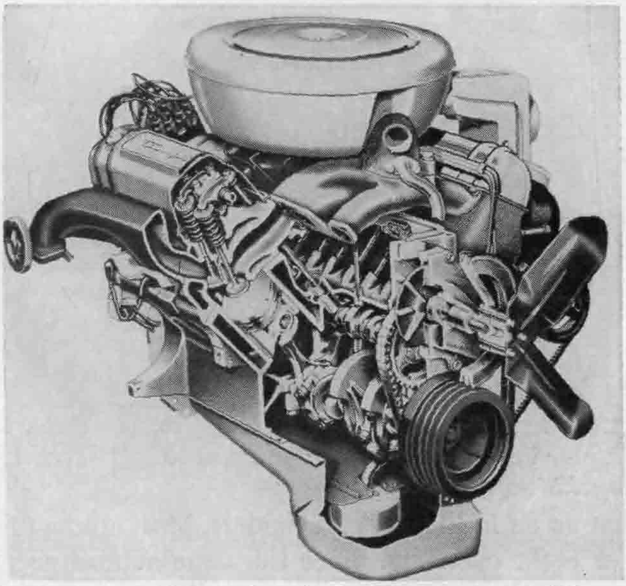


FIG. 1-3. Cutaway view of an eight-cylinder V-type engine. (*Mercury Division of Ford Motor Company*)

engine (in the engine cylinders or combustion chambers). This is in contrast to external-combustion engines (such as steam engines) where the combustion takes place *outside* the engine. It is the burning of the gasoline in the engine cylinders that produces the power. The power is carried from the engine through the power train to the car wheels so that the wheels turn and the car moves.

The fuel system plays a vital part in the power-producing process, since it supplies the gasoline to the engine cylinders. Before we describe how the fuel system does its job, let us first review the

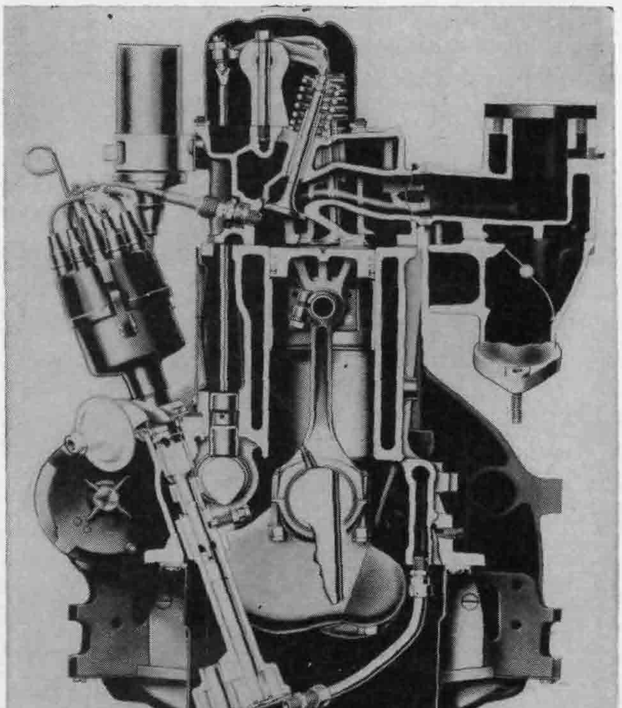


Fig. 1-4. Cross-sectional view of a six-cylinder engine. Piston is at top of stroke. Both piston and cylinder are shown cut in half. (*Chevrolet Motor Division of General Motors Corporation*)

actions that go on in the engine cylinders. Most automotive engines have six or eight cylinders. Since the same actions go on in each cylinder, we need to examine only one cylinder of the engine.

§4. The engine cylinder Figure 1-3 shows an engine cylinder, cut away so that the internal parts can be seen. This is the end cylinder of a six-cylinder engine; the other five cylinders are not shown. Figure 1-4 shows a cutaway view of a similar engine. These two pictures may be somewhat confusing since they show so many parts, so let's simplify the cylinder by showing it as nothing more than a round container, closed at one end and open at the other (Fig. 1-5), like a tin can with the bottom cut out. A movable piston fits into the cylinder. The piston is slightly smaller in size (or diameter) than the cylinder, so that it can slip up into the cylinder as shown in Fig. 1-5 (at *b*). Note that the cylinder is drawn as

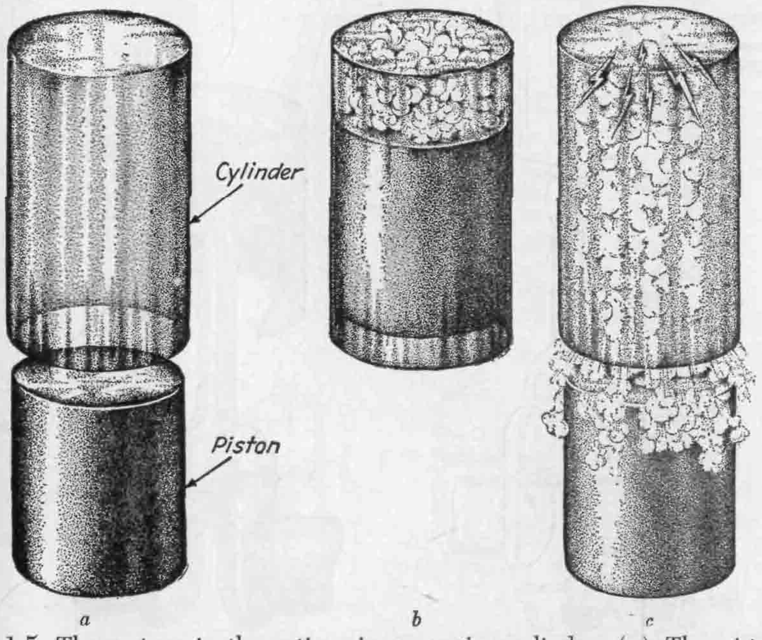


FIG. 1-5. Three steps in the actions in an engine cylinder. (*a*) The piston is a second cylinder that fits snugly into the engine cylinder. (*b*) When the piston is pushed up into the engine cylinder, air is trapped and compressed. The cylinder is drawn as though it were transparent so the piston can be seen. (*c*) As the pressure increases due to the burning of the gasoline vapor, the piston is pushed out of the cylinder.

though it were transparent so that the actions in the cylinder can be seen. For the moment, you can think of the piston as a solid plug which can be slid up into the cylinder. This action traps air in the cylinder and compresses it (Fig. 1-5*b*). If we could put some gasoline vapor in with the compressed air, and then apply a lighted match or an electric spark to the air-vapor mixture, it is obvious what would happen. There would be an "explosion" that would blow the piston out of the cylinder as shown in Fig. 1-5*c*.

This is actually what happens (with some modification) in each engine cylinder. A mixture of gasoline vapor and air enters the cylinder, the piston pushes up into the cylinder to compress the mixture, and then an electric spark ignites the compressed mixture

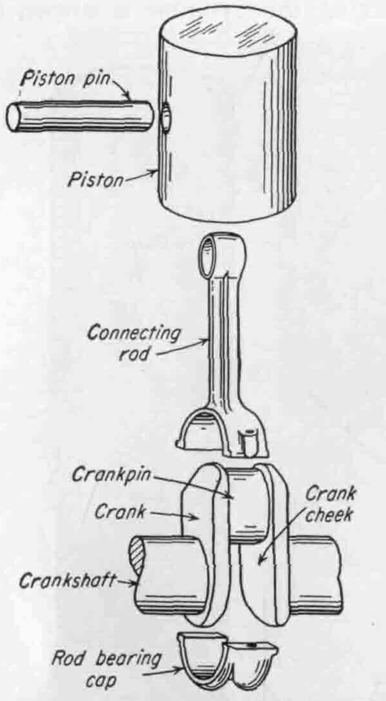


FIG. 1-6. A piston, connecting rod, piston pin, and crankpin on engine crankshaft in disassembled view.

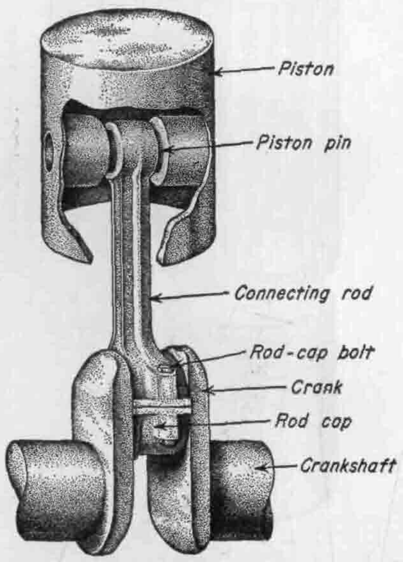


FIG. 1-7. Piston and connecting-rod assembly attached to crankpin on crankshaft. Piston is shown partly cut away so you can see how it is attached to connecting rod.

so that the piston is forced downward. Of course, in the engine the piston is not blown clear out of the cylinder; the piston simply moves up and down in the cylinder—up to compress the mixture, down as the mixture burns.

§5. Changing reciprocating motion to rotary motion The piston moves up and down in the cylinder. This straight-line motion is called *reciprocating* motion; the piston moves in a straight line. This straight-line motion must be changed to rotary motion before it can be used to make the car wheels rotate. A connecting rod and a crank on the engine crankshaft make this change (Fig. 1-6). The crank is an offset section of the crankshaft. It swings around in a circle as the shaft rotates. The connecting rod connects between the crankpin on the crank and the piston (Fig. 1-7). The crank end of the connecting rod is attached to the crankpin by fastening the rod cap to the connecting rod with the rod bolts. Bearings in the rod and cap permit the crankpin to rotate freely within the rod. The piston end of the connecting rod is attached to the piston

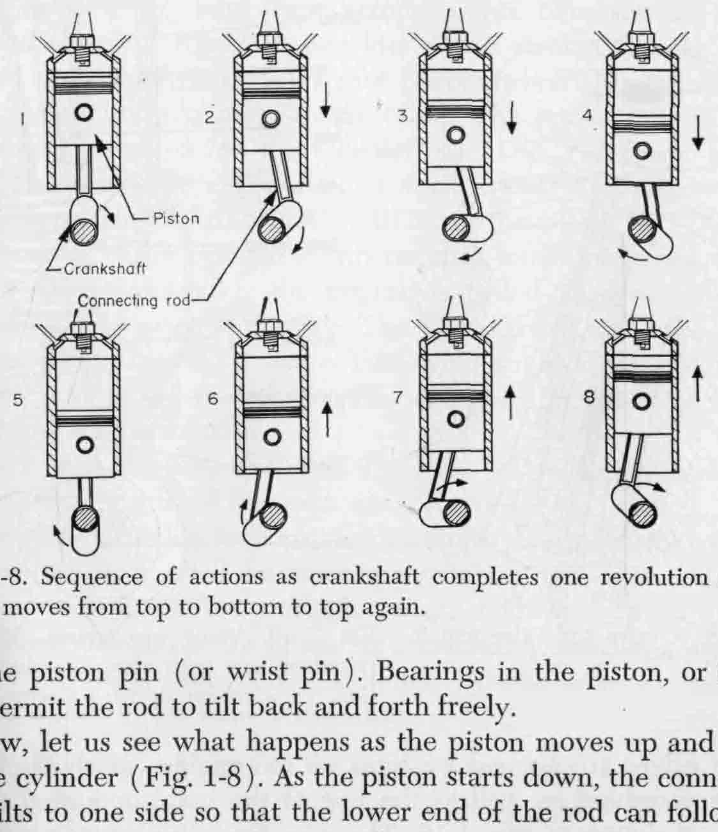


FIG. 1-8. Sequence of actions as crankshaft completes one revolution and as piston moves from top to bottom to top again.

by the piston pin (or wrist pin). Bearings in the piston, or in the rod permit the rod to tilt back and forth freely.

Now, let us see what happens as the piston moves up and down in the cylinder (Fig. 1-8). As the piston starts down, the connecting rod tilts to one side so that the lower end of the rod can follow the circular path of the crankpin. Study the sequence of action in Fig. 1-8 to see how the rod tilts first to one side and then to the other as the lower end moves in a circle with the crankpin.

§6. The valves There must be some means of getting the burned gasoline vapor out of the engine cylinder, and also of getting fresh charges of gasoline vapor and air into the cylinders. The engine valves do this job. There are two openings, or ports, in the enclosed end of the cylinder. One of these is shown in Fig. 1-3. There is a valve in each port. The valves are accurately machined plugs on long stems. When they are closed or seated (that is, moved down into the ports), the ports are sealed off and gas cannot pass through the ports. When the valve is opened (as shown in Fig. 1-9), gas can pass through the port.

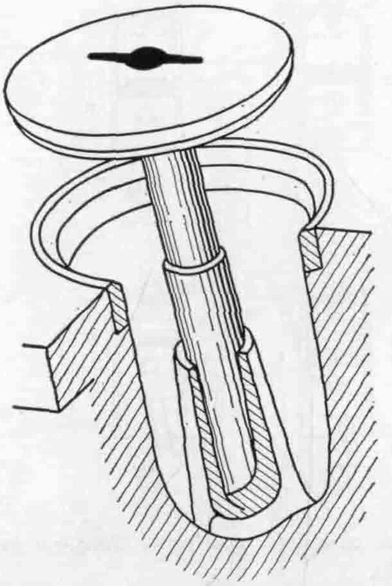


FIG. 1-9. A valve and valve seat in cylinder.

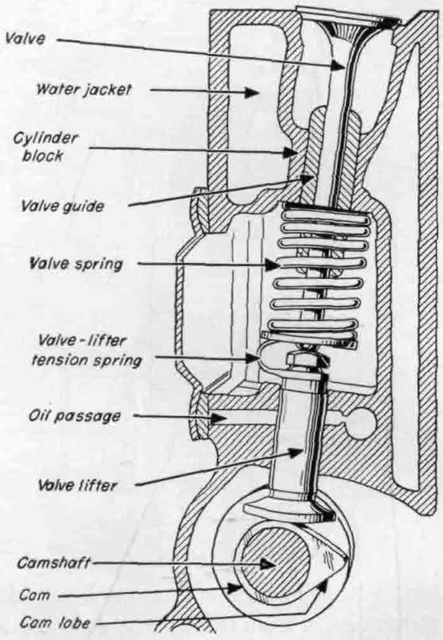


FIG. 1-10. Valve mechanism. Valve is raised off seat with every camshaft rotation. (*Studebaker-Packard Corporation*)

The valves are opened by cams on the engine camshaft. A cam on the camshaft, as well as the rest of the valve-operating mechanism, is shown in Fig. 1-10. The cam has a high point, or lobe; every time the cam rotates, the lobe comes around under the valve lifter and moves it upward. The lifter then carries this upward movement to the valve stem, causing the valve to move up, or open. Then, after the cam has turned enough to move the lobe out from under the lifter, the heavy valve spring pulls the valve back on its seat. The spring is attached to the lower end of the valve stem by a spring retainer and lock.

There is a cam for each valve (two cams per cylinder) on the engine camshaft. The camshaft is driven off the crankshaft by gears or by sprockets and a chain.

§7. Engine operation We have noted that the piston moves up and down in the cylinder and that the valves open and close to admit fresh charges of air and gasoline vapor and also to discharge burned gases. Let us see how these actions occur. The actions can be divided into four stages, or into four piston strokes. "Stroke" refers to the piston movement. A stroke occurs when the piston moves from one limiting position to the other. The upper limit of piston movement is called *top dead center,* or TDC. The lower limit of piston movement is called *bottom dead center,* or BDC. A stroke is piston movement from TDC to BDC, or from BDC to TDC.

When the entire cycle of events requires four piston strokes (two crankshaft revolutions), the engine is called a *four-stroke-cycle* engine, or a *four-cycle* engine. The four strokes are *intake, compression, power* and *exhaust.* (Two-cycle engines are also in use; in these, the entire cycle of events takes place in two strokes, or in one crankshaft revolution.)

NOTE: For the sake of simplicity in the following discussion, the valves are considered to open at TDC and BDC, that is, at the upper and lower limits of piston movement. Actually, they do not. The valves open well before the piston reaches BDC. Also, the illustrations of the four strokes (Figs. 1-11 to 1-14) are much simplified and show the intake and exhaust valves separated and placed on either side of the cylinder. This is done so that both can be shown in the same illustration.

§8. Intake (Fig. 1-11) On the intake stroke, the intake valve has opened. The piston is moving down (being pulled down by the rotation of the crankshaft). This piston movement creates a partial vacuum in the cylinder. In a later chapter in the book we will go into this matter in more detail. For the present, let us merely say that air rushes into the cylinder past the intake valve to "fill up" this vacuum. As the air moves toward the cylinder, it must pass through the fuel-system carburetor. There it is charged with gasoline vapor. Thus, it is a mixture of air and gasoline vapor that rushes into the cylinder as the piston moves down on the intake stroke.

§9. Compression (Fig. 1-12) After the piston moves down to BDC on the intake stroke, the intake valve closes. The lobe on the cam controlling the intake valve has moved out from under the valve lifter. Since the other valve is also closed, the upper end of the cylinder is sealed. Now, as the piston moves up (pushed up by the rotating crankshaft), the mixture of air and gasoline vapor that has

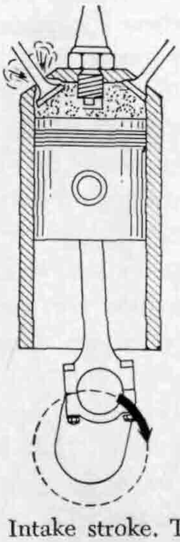


FIG. 1-11. Intake stroke. The intake valve (to left) has opened, and the piston is moving downward, drawing air and gasoline vapor into the cylinder.

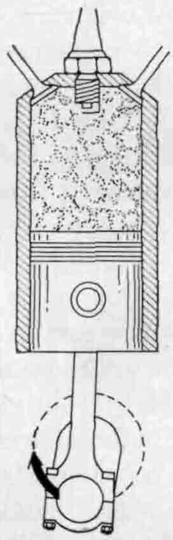


FIG. 1-12. Compression stroke. The intake valve has closed, and the piston is moving upward, compressing the mixture.

been drawn into the cylinder is compressed. By the time the piston has moved up to TDC, the mixture will have been compressed to a seventh or an eighth of its original volume. That is like taking a gallon of air and compressing it to a pint. This results in a fairly high pressure in the cylinder.

§10. Power (Fig. 1-13) About the time the piston reaches TDC on the compression stroke, an electric spark occurs at the cylinder spark plug. The spark plug is essentially two heavy wire electrodes;

the spark jumps between these electrodes. The spark is produced by the ignition system (discussed on a later page). It ignites, or sets fire to, the compressed air-gasoline-vapor mixture. Rapid combustion takes place; high temperatures and pressures result. At this instant, the resulting pressure on the top of the piston, pushing it down, may amount to as much as two tons (on a piston 3 inches in diameter). This powerful push forces the piston down, and a power impulse is transmitted to the crankshaft through the connecting rod and crank.

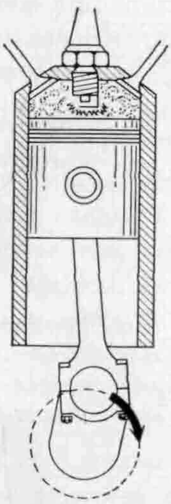


FIG. 1-13. Power stroke. The ignition system produces a spark that ignites the mixture. As it burns, high pressure is created which pushes the piston downward.

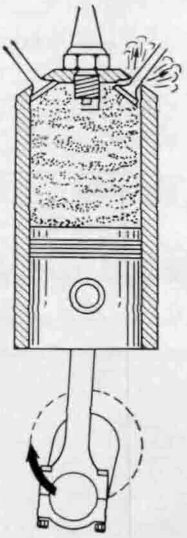


FIG. 1-14. Exhaust stroke. The exhaust valve (to right) has opened, and the piston is moving upward, forcing the burned gases from the cylinder.

§11. Exhaust (Fig. 1-14) The piston is forced down by the pressure of the burning gasoline vapor during the power stroke. When the piston reaches BDC, the exhaust valve opens. Now, as the piston starts back up again (pushed up by the rotating crankshaft), it forces the burned gases from the cylinder. By the time the piston has reached TDC, the cylinder is cleared of the burned gases. The exhaust valve closes and the intake valve opens. Then, the piston starts back down again on the next intake stroke. The four cycles, or piston strokes, are continously repeated all the time that the engine is running.

§12. Piston rings You can appreciate the fact that a great deal of pressure exists above the piston during the compression and

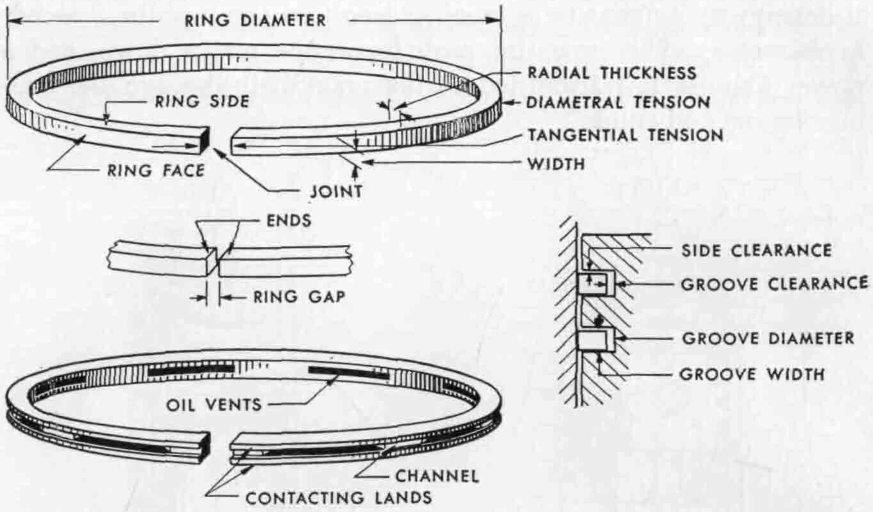


FIG. 1-15. A compression ring (top) and an oil-control ring (bottom), with various parts named. (*Sealed Power Corporation*)

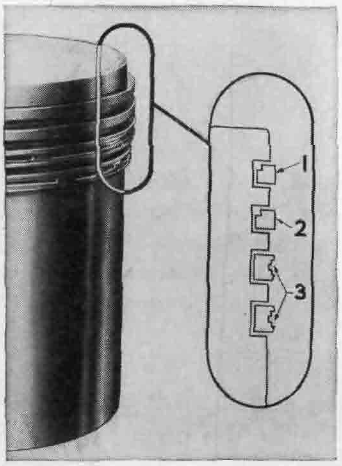


FIG. 1-16. External and sectional views of piston with four piston rings in place. The upper two, 1 and 2, are top and second compression rings. The lower two, 3, are oil-control rings. (*Plymouth Division of Chrysler Corporation*)

power strokes. To prevent the escape of much of this pressure past the piston (between the piston and cylinder wall), the piston must be equipped with rings. The reason is this: the piston cannot be machined accurately enough to provide a sealing fit with the cylinder wall. If it did make a gastight fit, then it would be too tight to slip up and down easily. Furthermore, changes in dimensions due to temperature changes might make it stick tight; this would mean that something might break (rod, piston, crankshaft). The metal of the piston expands with temperature increase; if the piston fit properly when cold, it would stick when hot. To provide a good seal that will expand and contract with changing temperatures (and also to compensate for cylinder-wall wear), piston rings are used.

Typical piston rings are shown in Fig. 1-15. The rings are of cast iron or similar metal. They have a joint which permits them to be expanded and slipped over the end of the piston. There are grooves in the piston into which the rings are installed (Fig. 1-16). Actually, only the upper two rings shown in Fig. 1-16 have the job of sealing in compression and combustion pressure. These rings, called the *compression* rings, do this by pressing tightly against the cylinder wall and also against the side of the ring groove in the piston. The lower two rings shown in Fig. 1-16 are *oil-control* rings. Their job is to scrape excessive amounts of lubricating oil off the cylinder walls. As we will mention again when we describe lubricating systems, considerable amounts of lubricating oil are thrown on the cylinder walls to provide for lubrication of the moving rings and piston. In fact, there is so much oil that if most of it were not removed, it would work up into the combustion chamber and burn, producing carbon that would interfere with valve and spark-plug action so that engine performance would be very poor. The *oil-control* rings scrape off most of this oil from the cylinder walls and return it to the oil reservoir (oil pan) at the bottom of the engine.

§13. Multiple-cylinder engines You will remember that the cylinder produces only one power impulse every four piston strokes. During exhaust, intake, and compression, the crankshaft is driving the piston, forcing it to push out the burned gases, to draw in a fresh charge, and to compress the charge. Thus, a one-cylinder engine would give power only one-fourth of the time and would not be smooth or powerful enough for automotive operation. To provide for a more continuous flow of power, modern automotive engines use four, six or eight cylinders. With a four-cylinder engine, the power impulses would follow one another so that there would be a power impulse going on all the time. With the six-cylinder engine, the power impulses would overlap to some extent while the eight-cylinder engine would have two power impulses going on at all times. This would give a relatively even flow of power.

§14. Engine flywheel Even though the power impulses of a multi-cylinder engine follow each other or overlap, additional smoothing out of the power impulses is desirable. The engine flywheel does this job and thus improves the smoothness of the engine. Figure 1-17 shows an engine crankshaft with the flywheel attached to one end. The flywheel is a relatively heavy metal wheel. It resists any sudden change of crankshaft (or engine) speed. Thus, when a

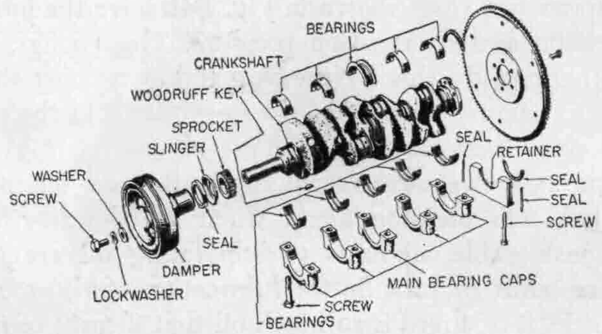
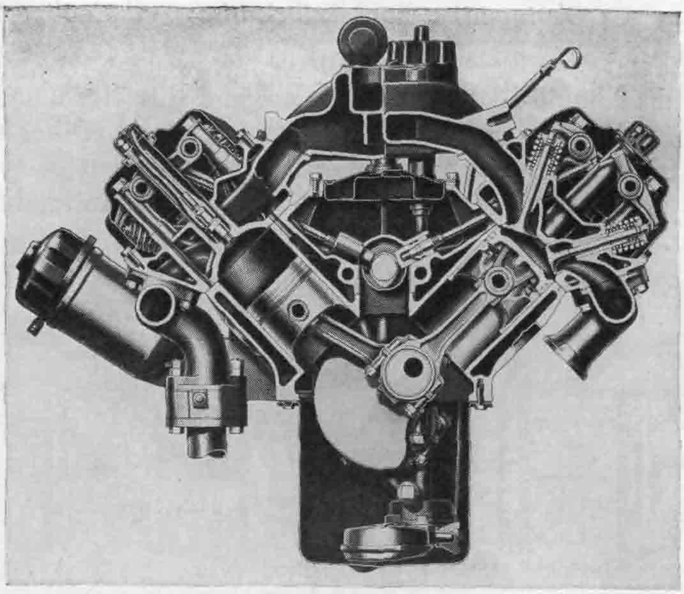


FIG. 1-17. Crankshaft and related parts used in an eight-cylinder V-type engine. (*Mercury Division of Ford Motor Company*)

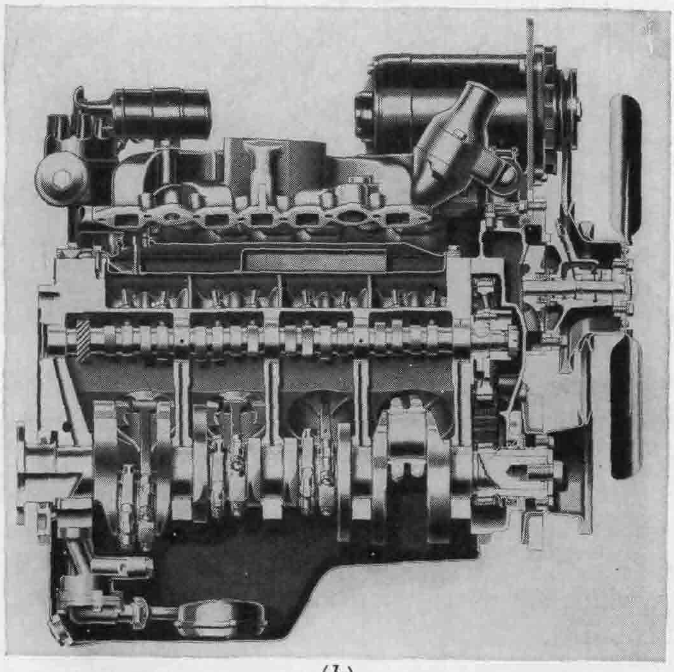
power impulse starts (with its initial high pressure), the crankshaft is given a momentary hard push (through the connecting rod and crankpin). But the flywheel resists the tendency for the crankshaft to surge ahead. Thus, the momentary power peaks are leveled off so that the engine runs smoothly.

The flywheel also serves as part of the engine clutch (on engines so equipped). In addition, the flywheel has teeth on its outer edge; the electric cranking-motor pinion teeth mesh with these teeth when the engine is being cranked for starting.

§15. Engine classifications Engines can be classified in several ways. They can be classified by the type of fuel they use [gasoline, LPG (liquefied petroleum gas), or diesel fuel oil]. Most of this book pertains to the gasoline fuel engine since most automotive engines use gasoline as fuel. Later chapters describe LPG and diesel fuel



(a)



(b)

FIG. 1-18. (*a*) Side sectional view and (*b*) end sectional view of a V-8 engine. This is called a *Fire Dome* engine by the manufacturer; the combustion chambers are hemispherical in shape. Note valve and push-rod arrangement. (*De Soto Division of Chrysler Corporation*) systems and the fuels these systems use. Engines can also be classified as liquid-cooled or air-cooled, and this distinction is discussed in the chapters on engine cooling systems. Other ways of classifying engines are by number and arrangement of cylinders, and by arrangement of valves. These are discussed in the following sections.

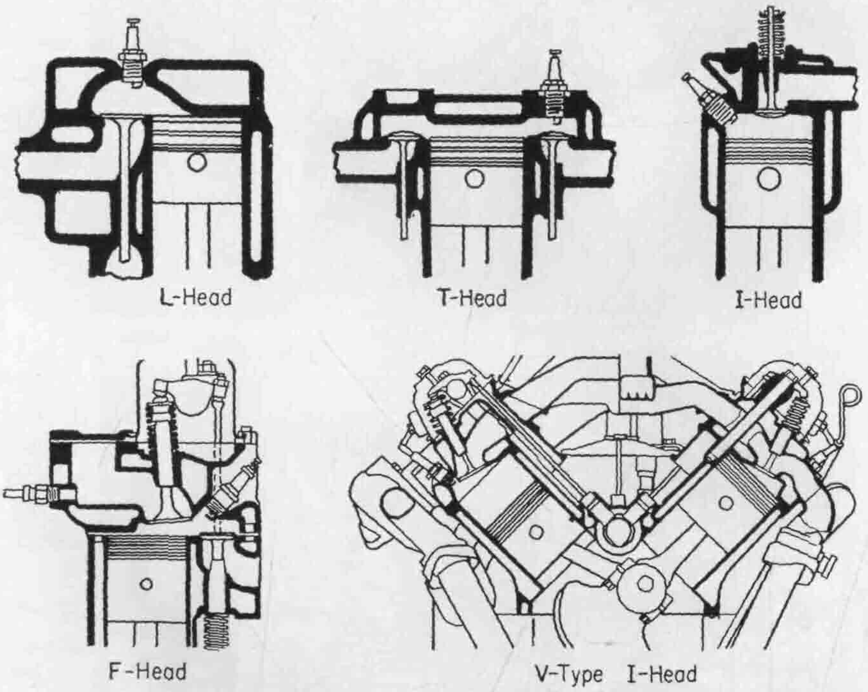


FIG. 1-19. Valve arrangements for various engines.

§16. Cylinder arrangements Most automotive engines have four, six, or eight cylinders. All cylinders are similar in construction and in operation. Four-cylinder and six-cylinder engines are in-line engines; that is, the cylinders are arranged in a single row (Fig. 1-2). Eight-cylinder engines may be in-line (all cylinders in a single row) or V-8. In the V-8, the cylinders are arranged in two rows, or banks, which are usually perpendicular (or 90 degrees) to each other (Fig. 1-18).

§17. Valve arrangements The valves may be in the block as shown in Figs. 1-2 to 1-4, or they may be in the cylinder head, above the cylinder, as shown in Fig. 1-18. An engine that has the valves in the block is called an *L-head* engine because the cylinder and combustion chamber are in the shape of an inverted "L." An engine that has the valves in the head is called an *I-head* engine (or *overhead-valve* engine) because the cylinder and combustion chamber are in the shape of an "I." There is a type of engine that has valves in

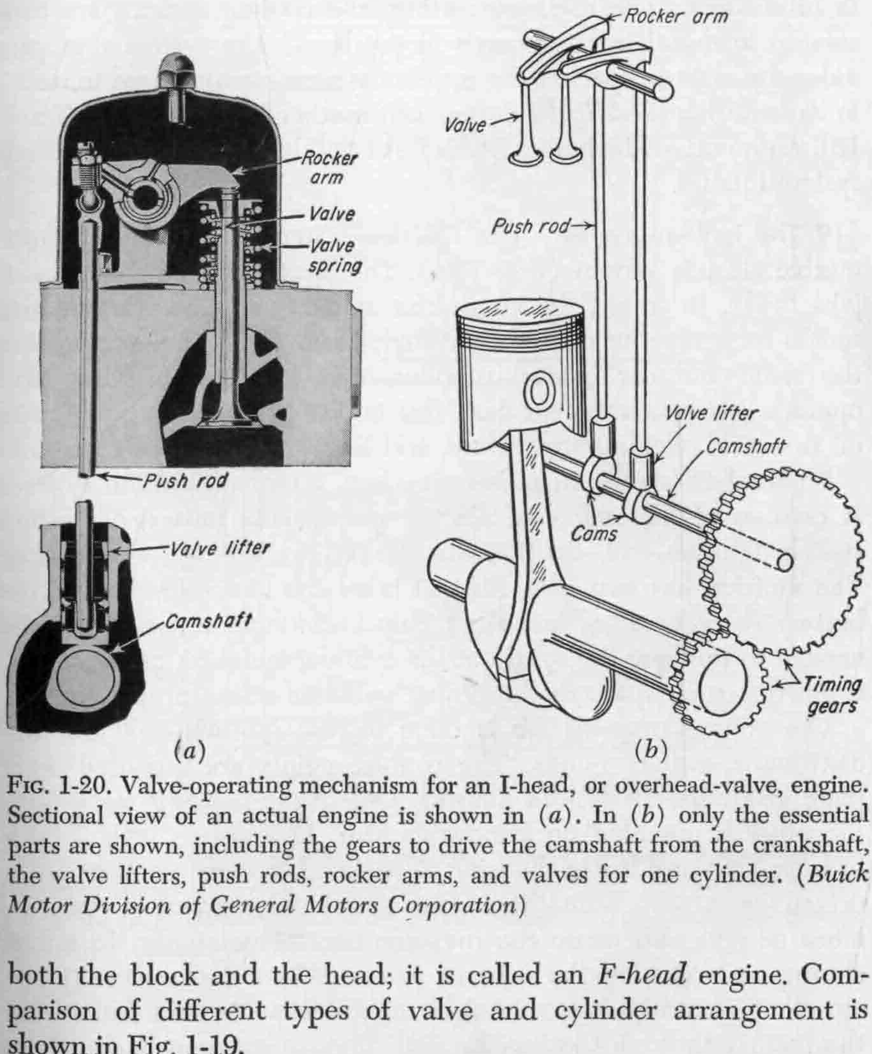


FIG. 1-20. Valve-operating mechanism for an I-head, or overhead-valve, engine. Sectional view of an actual engine is shown in (*a*). In (*b*) only the essential parts are shown, including the gears to drive the camshaft from the crankshaft, the valve lifters, push rods, rocker arms, and valves for one cylinder. (*Buick Motor Division of General Motors Corporation*)

both the block and the head; it is called an *F-head* engine. Comparison of different types of valve and cylinder arrangement is shown in Fig. 1-19.

Figure 1-10 shows the valve mechanism in an L-head engine. Figure 1-20 shows the valve mechanism for an overhead-valve (or I-head) engine. Note that a rocker arm and push rod are needed for each valve in order to push *down* on the valve stem and thus open the valve. In the L-head engine the valve lifter pushes *up* on the valve stem.

§18. Engine accessory system The engine requires four accessory systems to supply it with fuel and electric sparks, to cool it, and to lubricate it. The fuel, lubricating, and cooling systems are considered in detail in later pages in the book. The system that provides the electric sparks (the ignition system) is discussed in detail in *Automotive Electrical Equipment* (another book in the McGraw-Hill Automotive Mechanics Series). A brief discussion of the ignition system follows.

§19. The ignition system The ignition system is part of the automotive electric system (Fig. 1-21). The electric system has several jobs to do. It cranks the engine for starting, supplies the electric sparks to ignite the compressed charges in the cylinders, operates the radio and car heater, supplies light for night driving, and operates gauges on the car dash that indicate battery charging rate, oil pressure, engine temperature, and level of fuel in the fuel tank.

Figure 1-22 shows, in schematic view, a typical ignition system. It consists of the source of electric power (the battery), ignition switch, ignition coil, ignition distributor, spark plugs, and wiring. The ignition has two jobs. First, it takes the low voltage from the battery (or generator) and steps it up to the several thousand volts needed to produce the sparks at the cylinder spark plugs. Secondly, it delivers each spark to the proper cylinder at the proper instant.

The voltage step-up job is done by the ignition coil and the distributor contact points. The contact points are mounted on a plate inside the distributor housing. One of the points is stationary; the other is mounted on a movable arm. This arm is moved by a breaker cam inside the housing. The breaker cam revolves (it is driven by a gear from the engine camshaft), and as it does so, lobes on the cam cause the movable contact-point arm to move, closing and opening the contact points. When the contact points are closed (and ignition switch is on), electric current flows from the battery through the ignition coil. Then, a moment later, as the cam turns further, a lobe on the cam moves the arm and separates the contact points. The current stops flowing. During the time that current flows, the ignition coil becomes "loaded" with electric energy. Then, when the contact points separate and the current stops flowing, the electric energy is released from the coil in the form of a high-voltage surge.

NOTE: An ignition capacitor, or condenser, is connected across

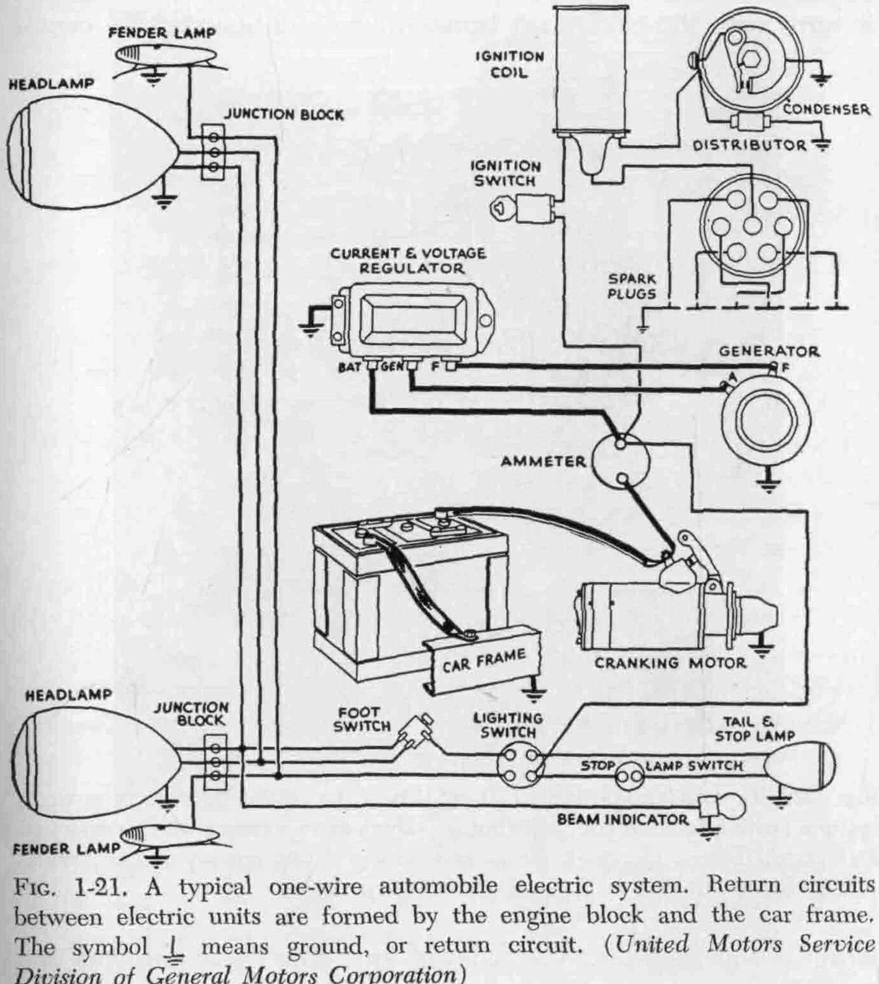


FIG. 1-21. A typical one-wire automobile electric system. Return circuits between electric units are formed by the engine block and the car frame. The symbol ⏚ means ground, or return circuit. (*United Motors Service Division of General Motors Corporation*)

the contact points to prevent the high-voltage surge from discharging across the contact points. This saves the surge for its designed purpose, which is to produce a spark at a spark-plug gap.

The high-voltage surge produced by the coil is carried by wires to the distributor cap and from there to the spark plug of the cylinder that is ready to fire (air-fuel mixture compressed). The surge passes through the center terminal of the distributor cap. The center terminal is connected by a wire to the coil. The center terminal is connected inside the cap by a contact spring to the distributor rotor. The rotor is mounted on the breaker cam so that it turns with the cam. As it turns, it connects between the center

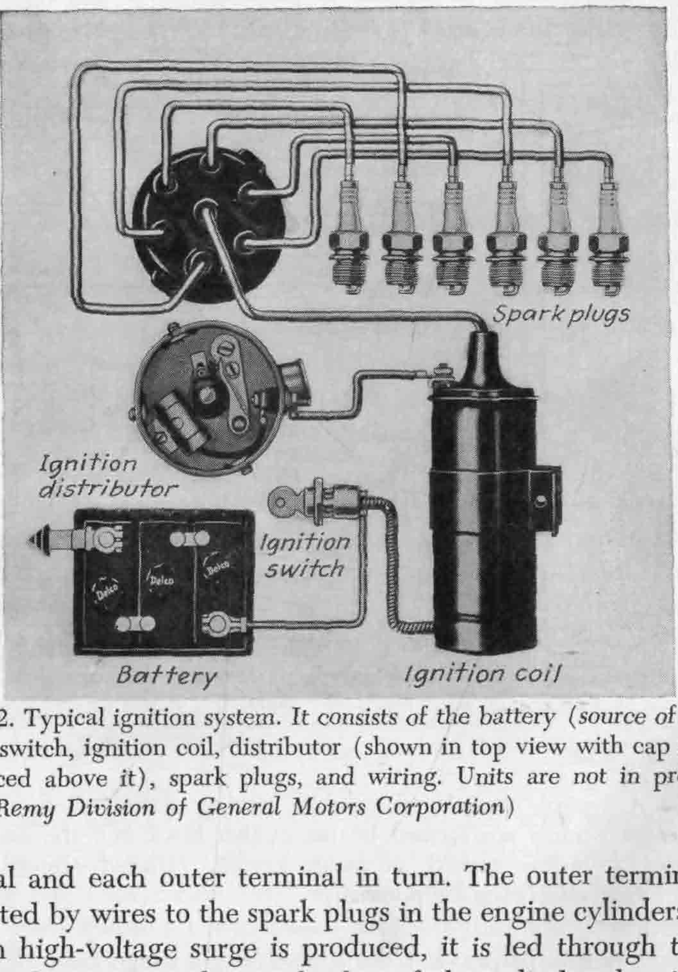


FIG. 1-22. Typical ignition system. It consists of the battery (source of power), ignition switch, ignition coil, distributor (shown in top view with cap removed and placed above it), spark plugs, and wiring. Units are not in proportion. (*Delco-Remy Division of General Motors Corporation*)

terminal and each outer terminal in turn. The outer terminals are connected by wires to the spark plugs in the engine cylinders. Thus, as each high-voltage surge is produced, it is led through the cap, rotor, and wiring to the spark plug of the cylinder that is ready to fire (*piston nearing TDC on the compression stroke*).

§20. Operation of ignition-advance mechanisms When the engine is idling, the sparks are timed to appear in the engine cylinders just before the pistons reach TDC on their compression strokes. But at higher speeds, the air-fuel mixture has less time to ignite and burn. If ignition still took place just before TDC on the compression stroke, the piston would be up over the top and moving

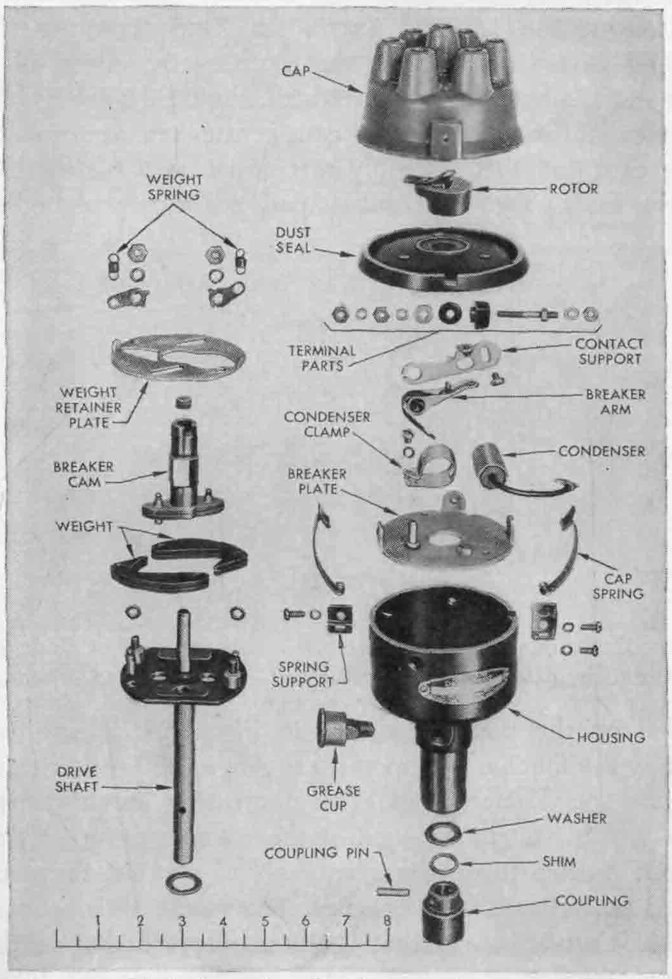


Fig. 1-23. Disassembled view of a distributor. Advance mechanism is to left. (*Delco-Remy Division of General Motors Corporation*)

down before the mixture was well ignited. This means that the piston would be moving away from the pressure rise; much of the energy in the burning fuel would be wasted. However, if the mixture is ignited earlier in the compression stroke (at high engine speed), the mixture will be well ignited by the time the piston reaches TDC. Pressure will go up and more of the fuel energy will be used.

1. *Advance based on speed.* To ignite the mixture earlier at high speed, a spark-advance mechanism is used. This mechanism is incorporated in the ignition distributor. One type consists of a centrifugal device that pushes the breaker cam ahead of the distributor shaft as engine speed increases. Figure 1-23 shows the parts of this mechanism. The breaker cam is attached to an oval-shaped advance cam and this assembly sets down on a plate attached to the drive shaft. Two crescent-shaped advance weights are also

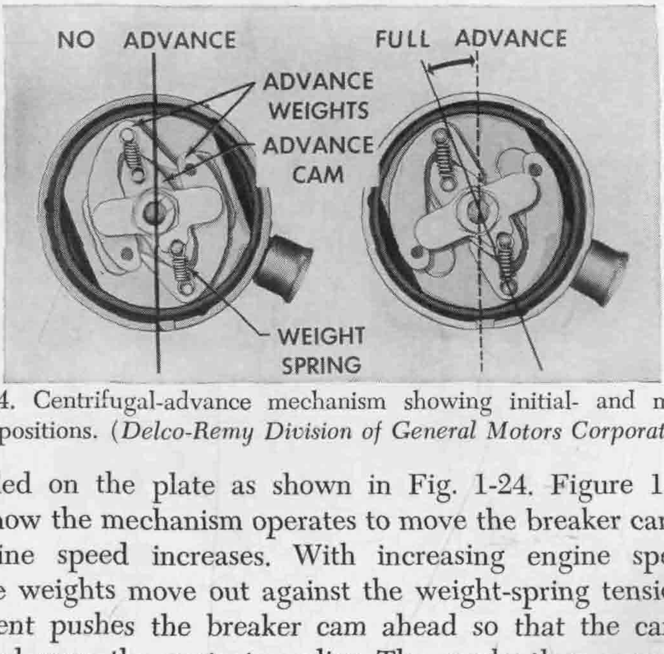


FIG. 1-24. Centrifugal-advance mechanism showing initial- and maximum-advance positions. (*Delco-Remy Division of General Motors Corporation*)

assembled on the plate as shown in Fig. 1-24. Figure 1-24 also shows how the mechanism operates to move the breaker cam ahead as engine speed increases. With increasing engine speed the advance weights move out against the weight-spring tension. This movement pushes the breaker cam ahead so that the cam lobes close and open the contacts earlier. The sparks thus occur earlier; the spark is advanced so that ignition occurs earlier in the compression stroke.

Different engines require different amounts of spark advance at various speeds. Typical advance curves are shown in Fig. 1-25. In curve *A*, the spark is timed to occur just a few degrees of crankshaft rotation before TDC during idle. Then, as engine speed is increased, the spark moves ahead, or advances, until it reaches a maximum of 28 degrees at 2,900 rpm (revolutions per minute).

Curve B is a little more complicated. It "dog-legs," or changes slope, at 1,500 rpm. A curve is worked out for each engine so that the advance at any particular speed will provide best performance. The mechanism is then built to provide this advance.

Figure 1-26 illustrates a distributor that achieves spark advance with increasing speed by a different method. In this unit the contacts are mounted on a movable breaker plate. The plate is linked to an airtight diaphragm. Movement of the diaphragm will cause

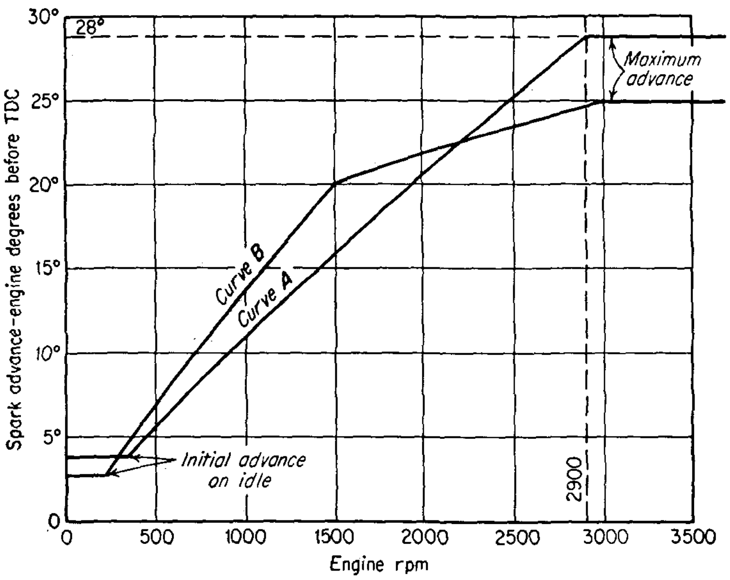


FIG. 1-25. Typical centrifugal-advance curves.

the plate to rotate a few degrees and carry the contacts around with it. This movement causes the contacts to be closed and opened earlier so that a spark advance is produced. The plate rotation results from the vacuum-line connection between the airtight diaphragm on the distributor and an opening in the carburetor venturi. As we will explain later, vacuum increases in the carburetor venturi with increasing engine speed (§47). The greater the vacuum (or the greater the engine speed), the further the diaphragm is moved and the more the plate moves to advance the spark.

2. *Advance based on intake-manifold vacuum.* With a partly closed throttle valve, there is a partial vacuum in the intake mani-

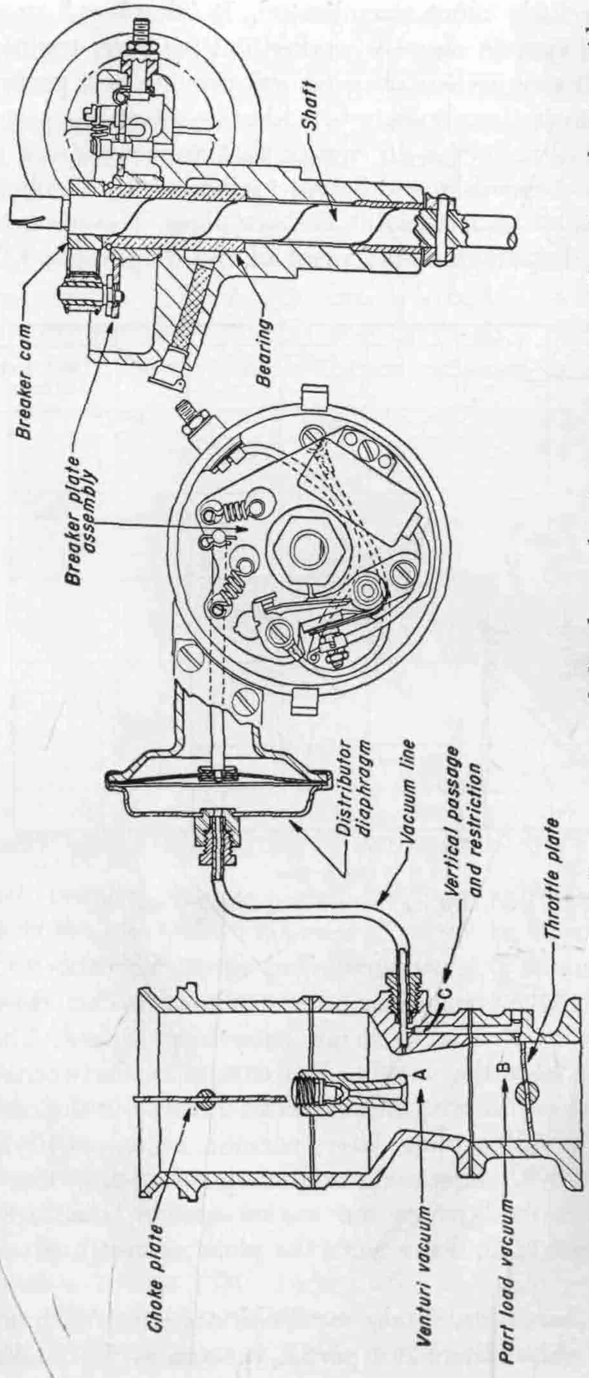


FIG. 1-26. Top and sectional views of a full-vacuum-control distributor showing vacuum connections to carburetor with which it is used. (*Ford Motor Company*)

fold. Less air-fuel mixture gets into the engine cylinders and it is therefore less highly compressed. This means the mixture burns more slowly. An additional spark advance, under these conditions, will allow the mixture ample time to burn and give up its energy to the piston. Spark advance based on intake manifold vacuum is achieved by an airtight diaphragm linked to a movable breaker plate. This type of arrangement is shown in Fig. 1-26. A vacuum connection is made to an opening just above the edge of the throttle plate (*B* in Fig. 1-26) in the carburetor. Whenever the throttle is opened, its edge moves past the opening, thus introducing the intake manifold into the tube. This vacuum then causes diaphragm and breaker plate movement. The spark is advanced. Note that advance is based, in this arrangement, on manifold vacuum, which is *part-throttle* vacuum. When the throttle is opened wide, there is no appreciable manifold vacuum and thus there will be no vacuum advance from this effect.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

Now that you have completed a chapter in the book, you will want to test your knowledge of the subjects covered in the book. The questions that follow have two purposes. One is to test your knowledge. The second purpose is to help you review the chapter. The chances are that you will not be able to answer, offhand, all the questions. If this happens, turn back into the chapter and reread the pages that will give you the answer. Don't be discouraged if you can't answer all the questions. Most good students reread their lessons several times in order to be sure that the essential information will "stick" with them. Rereading the pages and rechecking the questions will help you learn how to pick out and remember the important facts in the book. And it is these important facts that will help you when you go into the automotive shop, office, or laboratory.

Correcting Parts Lists

The purpose of this exercise is to give you practice in spotting unrelated parts in a list. For example, in the list, *cylinder, piston, rings, wheel, flywheel, crankshaft,* you can see that *wheel* does not belong because it is the only part named that does not belong in an engine.

In each of the lists, you will find one item that does not belong. Write down each list in your notebook, but do not write down the item that does not belong.

1. The four piston strokes are intake, compression, injection, power, exhaust
2. The engine parts that change the reciprocating motion of the piston to rotary motion include the connecting rod, crank on crankshaft, cam on camshaft
3. The valve mechanism in the L-head engine includes the camshaft, valve spring, crankshaft, valve, spring retainer, lock
4. The two types of piston rings are oil-control rings, compression rings, performance rings
5. The ignition system includes the ignition coil, ignition distributor, ignition switch, spark plugs, cranking motor, wiring

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The connecting rod is attached to the piston by the *rod cap* *piston pin* *cap bolts* *cap bearing*
2. The connecting rod is attached to the crankpin on the crankshaft by the *piston pin* *crank* *rod cap* *rod boots*
3. In the standard engine each cylinder has *one valve* *two valves* *three valves* *four valves*
4. The two types of engine valves are *intake and port* *intake and inlet* *intake and exhaust*
5. The four strokes in the engine are, in order of occurrence, *intake, power, exhaust, and compression* *intake, exhaust, power and compression* *intake, compression, power, and exhaust*
6. During the power stroke, the intake and exhaust valves are, respectively, *closed and opened* *opened and closed* *closed and closed*
7. The device for smoothing out the power impulses from the engine is called the *crankshaft* *camshaft* *flywheel* *clutch*
8. The camshaft has a separate cam for each *engine valve* *engine cylinder* *piston* *crankpin*
9. Two parts that the I-head valve mechanism has that the L-head valve mechanism does not are the *push rod and rocker arm* *valve lifter and spring* *camshaft and valve lifter* *lock retainer and lock*

10. In the ignition system the high-voltage surges produced by the coil as the contact points separate are carried through the distributor cap and rotor to the *ignition switch* *spark plugs* *battery or source of power* *capacitor*

SUGGESTIONS FOR FURTHER STUDY

If you would like to study the engine and engine-component systems further, there are several things you can do. For one thing, you can read the *Automotive Engines* and the *Automotive Electrical Equipment* books (two other books in the McGraw-Hill Automotive Mechanics Series). Also, you can inspect your own and your friends' cars as well as cars and engine components in the school automotive shop. You can go to a friendly automotive service shop where repair work on engines is done. By watching what goes on in the ordinary work of the day, you will learn much about these automotive components. Perhaps you can borrow shop-repair manuals from your school automotive shop library or from the car-dealer service shop. Your school may have cutaway models of engines or other automotive parts. By studying all this material, you will better understand the construction and operation of the engine and the engine-accessory systems.

2: Fuel-system fundamentals

THERE ARE two general types of fuel systems: the type with a carburetor such as is used in most cars and the fuel-injection fuel system that is beginning to come into common use. This chapter describes the fundamentals of the carburetor-type fuel system. Chapter 6 discussed the fuel-injection system.

§21. **Purpose of the fuel system** The fuel system is designed to store liquid gasoline and to deliver it to the engine cylinders on the intake strokes in the form of vapor mixed with air. The fuel system must vary the proportions of air and gasoline to meet the requirements of different operating conditions. For example, during initial starting with a cold engine, the fuel system must deliver a very rich mixture (rich in gasoline) of about 9 pounds of air to 1 pound of gasoline. Then, after the engine has warmed up, the mixture must be leaned out (made less rich) to about 15 pounds of air to 1 pound of gasoline. For acceleration or high-speed operation, the mixture must again be enriched.

§22. **Components in the fuel system** The fuel system (Fig. 2-1) consists of the fuel tank, fuel gauge, fuel pump, carburetor, intake manifold, connecting fuel lines, and the accelerator pedal and linkage. The accelerator pedal controls the amount of air-fuel mixture entering the engine cylinders, and thus the amount of power the engine produces. The fuel tank provides a reservoir, or storage space, for gasoline. The fuel gauge has an indicator needle on the car dash to indicate how full the fuel tank is. The fuel pump delivers gasoline from the fuel tank to the carburetor, and the carburetor mixes the gasoline with the air passing into the engine.

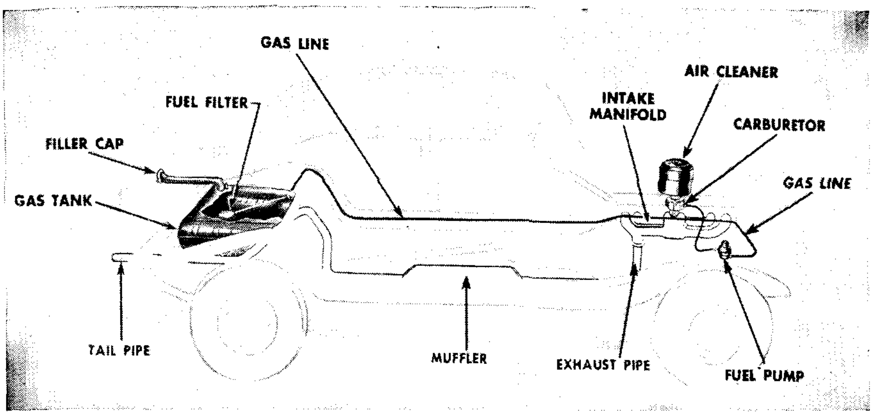


FIG. 2-1. Fuel system in phantom view.

§23. Atoms and elements Before we go into detail on how the carburetor and fuel system operate, let us talk about something that, at first, may seem unrelated to the subject. We refer to *atoms* and *elements*. As we look around us, we can see thousands of different substances and materials, from wood to steel, from glass to cloth, from gasoline to water. Yet the amazing fact is that all these many substances are made out of only a few different types of "building blocks" called *atoms*.

Actually, there are about ninety different kinds of atoms. Each has a special structure that makes it different from other atoms, and each has a special name such as iron, copper, hydrogen, sulfur, tin, oxygen, and so on. A piece of iron, for example, is made up entirely of one particular variety of atom. A quantity of the gas oxygen is made up of a great number of another type of atom. Any substance made up entirely of only one type of atom is called an *element*. The table on page 30 lists a number of the more common elements.

The ninety some kinds of atoms can combine in many ways to form hundreds of thousands of different combinations, or compounds. We can compare this to the 26 letters of the alphabet, which can be combined in many ways to form the thousands of words in our language. Thus, salt, water, wood, glass, gasoline, the very blood and bones in our bodies are made up of compounds produced by the combining of a few types of atoms. Salt is made up of atoms of the elements sodium and chlorine. Water is made up of atoms of the elements of hydrogen and oxygen.

TABLE OF ELEMENTS

Name	*Symbol*	*Atomic number*	*Approximate atomic weight*	*Electron arrangement*
Aluminum	Al	13	27	·2)8)3
Calcium	Ca	20	40	·2)8)8)2
Carbon	C	6	12	·2)4
Chlorine	Cl	17	35.5	·2)8)7
Copper	Cu	29	63.6	·2)8)18)1
Hydrogen	H	1	1	·1
Iron	Fe	26	56	·2)8)14)2
Magnesium	Mg	12	24	·2)8)2
Mercury	Hg	80	200	·2)8)18)32)18)2
Nitrogen	N	7	14	·2)5
Oxygen	O	8	16	·2)6
Phosphorus	P	15	31	·2)8)5
Potassium	K	19	39	·2)8)8)1
Silver	Ag	47	108	·2)8)18)18)1
Sodium	Na	11	23	·2)8)1
Sulfur	S	16	32	·2)8)6
Zinc	Zn	30	65	·2)8)18)2

§24. Size of atoms Individual atoms are far too small to see. There are billions upon billions of atoms in a single drop of water. A cubic inch of the gas hydrogen (at a temperature of 32° and at atmospheric pressure) contains about 880,000,000,000,000,000,000 (880 billion billion) atoms. To give you an idea of how small atoms really are, suppose we could expand this cubic inch until it was large enough to contain the earth. That means each edge would measure 8,000 miles (instead of an inch). If the atoms were expanded in proportion, each atom would then measure about 10 inches in diameter.

§25. Atomic structure All of us, in this atom-bomb age where "splitting the atom" is commonplace, have heard something of the atom. We have mentioned that there are more than ninety varieties of atoms. But basically, all atoms are composed of no more than three fundamental particles called *electrons, protons,* and *neutrons.* For instance, the hydrogen atom is made up of a proton at its center (or nucleus) and an electron circling the proton at high speed (Fig. 2-2). The proton has a charge of positive electricity (indicated by a + sign). The electron has a charge of negative electricity (indicated by a − sign). There is a strong attraction between positive and negative charges; this attraction tries to pull the electron into the nucleus. But balancing this pull is the tendency that the electron has to fly away from the nucleus due to its rotary motion (that is,

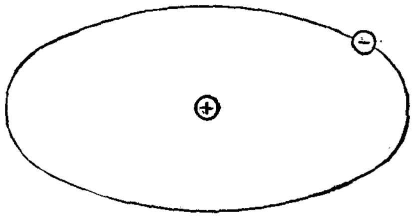


Fig. 2-2. The hydrogen atom consists of two particles, a proton at the center, or nucleus, and an electron that circles the proton.

the centrifugal force). This is the same balancing of forces you get when you whirl a ball on a rubber band around your hand (Fig. 2-3). The rotary motion (or centrifugal force) tends to move the ball away from your hand, but the rubber band (or attractive force) keeps the ball moving in a circle around your hand.

The helium atom (helium, like hydrogen, is a gas) has 2 protons in its nucleus and 2 electrons circling the nucleus. In addition, it has 2 neutrons in its nucleus (Fig. 2-4). The apparent function of the 2 neutrons is to hold the two protons together, though how they do this is not known. But if the neutrons were absent, the protons would fly apart, and there would be no helium atom. The reason the two protons would fly apart is that their positive charges repel each other, *if the neutrons are not present.* The neutrons are neutral electrically; they have no electric charge.

The atoms of the other elements are still more complicated than the hydrogen atom; they have more protons, more neutrons, more electrons. Lithium (a light metal), for example, has 3 protons, 4 neutrons, and 3 electrons. Next comes beryllium (another light metal) with 4 protons, 5 neutrons, and 4 electrons; boron with 5 protons, 5 neutrons, and 5 electrons; carbon with 6,6, and 6; nitrogen with 7,7, and 7; oxygen with 8,8, and 8. Note that each atom normally has the same number of electrons as protons. This makes the atom electrically neutral since there is a negative electrical charge (or electron) for every positive charge (or proton).

§26. Molecules We have already mentioned that the many substances, or compounds, in the world are made up of different combinations of atoms. Whenever two or more atoms combine,

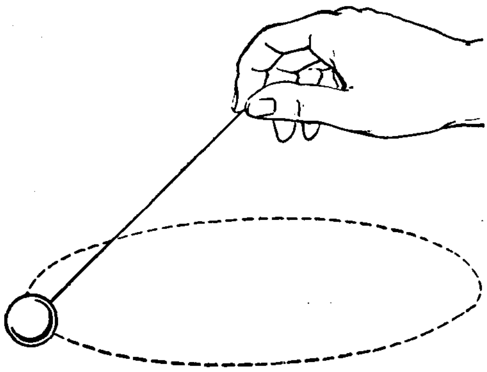


Fig. 2-3. The electron in a hydrogen atom circles the proton like a ball on a rubber band swung around the hand.

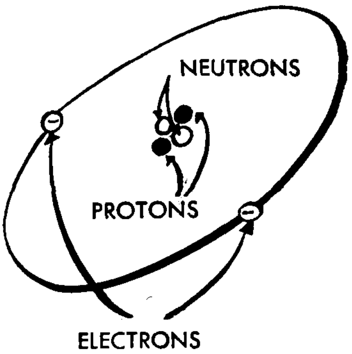


Fig. 2-4. A helium atom.

they form a larger particle called a *molecule*. This is like combining *letters* to form *words*. For example, when two atoms of hydrogen and one atom of oxygen are combined, a molecule of water is formed. When an atom of carbon is combined with two atoms of oxygen, a molecule of carbon dioxide is formed. There are literally millions of combinations, or molecules, that the various elements can form. Some molecules have only two or three atoms, other molecules may contain tens of thousands of atoms. The molecules of albumin (a constituent of blood plasma) have more than ten thousand atoms.

When atoms combine to form molecules, or molecules are changed by the addition or subtraction of atoms, the action is called a *chemical reaction.* In other words, the atoms react with each other.

§27. Combustion Combustion, or fire, is a common chemical reaction that involves atoms of the gas oxygen and atoms of other elements such as hydrogen or carbon. Combustion takes place in the engine cylinders. You will recall that air and gasoline vapor are mixed in the carburetor and then the mixture is ignited, or set on fire, in the engine cylinders. The air contains oxygen (about one-fifth of the air is oxygen). Gasoline is made up essentially of hydrogen and carbon molecules (and thus it is called a *hydrocarbon*).

An oxygen atom has eight protons and eight neutrons in its nucleus, and eight electrons circle the nucleus in two separate paths, or orbits (Fig. 2-5). The inner orbit has 2 electrons. The

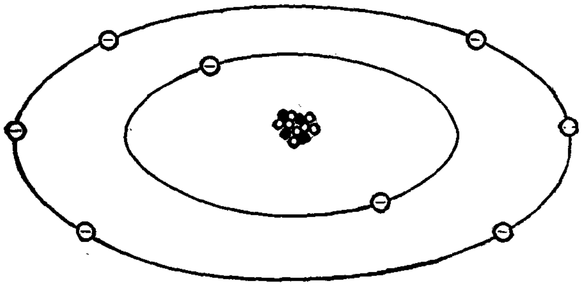


FIG. 2-5. An atom of oxygen.

outer orbit has 6 electrons. But the outer orbit has "room" for 8 electrons. It will, in fact, take on 2 additional electrons if free electrons are nearby. The hydrogen atom has 1 proton in its nucleus and 1 electron, as has already been mentioned.

When the gasoline burns, its molecules split into hydrogen and carbon atoms. Then these atoms combine with oxygen atoms. For instance, when the hydrogen atoms and oxygen atoms combine, the action is about as follows. Two hydrogen atoms lose their electrons as an oxygen atom "grabs" these "lost" electrons. The 2 electrons "fill up" the outer electron orbit of the oxygen atom. But this gives the oxygen atom two negative electric charges. Meantime, the 2 hydrogen atoms are left with positive electric charges (from their protons). The resulting electrical attraction between the hydrogen and oxygen atoms causes them to combine into a molecule with the chemical symbol H_2O and the common name *water* (Fig. 2-6).

At the same time, the carbon atoms are combining with oxygen atoms. A carbon atom has 6 protons and 6 neutrons in its nucleus and 6 electrons circling the nucleus in two orbits. In the combustion process, the 4 electrons are "grabbed" by 2 oxygen atoms somewhat as shown in Fig. 2-7. Then, because of the resulting positive and negative charges of the carbon and oxygen atoms, they

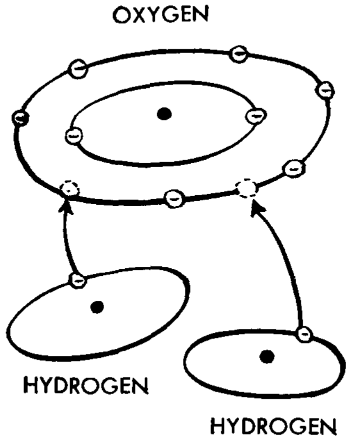


FIG. 2-6. An atom of oxygen uniting with two atoms of hydrogen to form a molecule of water (H_2O).

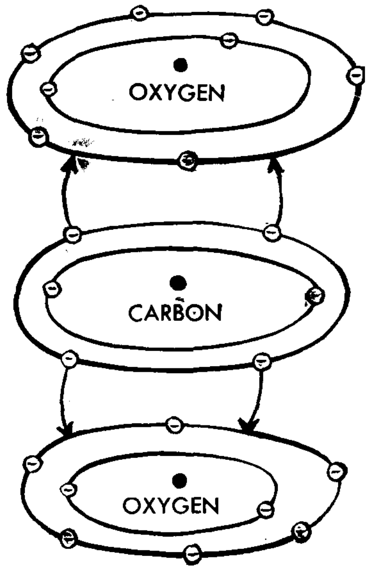


FIG. 2-7. One atom of carbon uniting with two atoms of oxygen to form a molecule of carbon dioxide (CO_2).

combine. One carbon atom combines with 2 oxygen atoms to form carbon dioxide, or CO_2.

To sum up, in the combustion process in the engine cylinders, the oxygen in the air unites with the hydrogen and carbon atoms in the gasoline to form H_2O and CO_2 (water and carbon dioxide).

§28. Heat During combustion, as described in the previous section, a great deal of heat is produced. All of us have a general idea of what is meant by the word "heat." But the scientific explanation of the word may not be familiar to us. For actually, to heat a substance is to set the molecules of that substance into more rapid motion.

We tend to think that the molecules of a piece of wood or iron or any other solid are motionless. However, they are in motion, even though they move in rather restricted paths. But the higher the temperature, the faster the motion of the molecules. When iron is heated to a high enough temperature, the molecules are moving so fast that the iron actually melts.

§29. Change of state When iron, or ice, or any similar solid melts, it undergoes a *change of state* (it changes from a solid to a liquid). Then, if it is further heated, it undergoes another change of state (from a liquid to a vapor). Conversely, if the vapor is cooled, it will change back to a liquid, and on further cooling, back to a solid. All these changes are simply indications of the change in the speed of the molecular motion.

For example, in ice, the water molecules are moving slowly and in restricted paths. But if ice is heated in a pan over a fire, the molecules will move faster and faster. As this happens, the molecules begin to break out of their restricted paths; the ice melts. Then, presently, the molecules are moving so fast that they jump clear of the water; the water boils, or turns to vapor.

Let us take another look at our pan of ice which changes to water and then to vapor. The fire under the pan is produced by oxygen atoms uniting with carbon and hydrogen atoms. Regardless of what fuel is used (gasoline, coal, wood, gas, kerosene, oil), there are hydrogen and carbon atoms in it that unite with the oxygen in the air as already described (§27). The H_2O and CO_2 molecules that are formed during this process are very fast-moving. As the molecules form, they dart off in all directions. Many of them bombard the bottom of the pan, almost like so many tiny baseballs thrown against a barn door. This bombardment sets the molecules of metal forming the pan into rapid motion (the pan gets hot). The metal molecules, in turn, hammer against the ice molecules, setting them into rapid motion. The ice melts. Then, as the bombardment continues, the water boils.

NOTE: This is only a partial explanation of what takes place in a fire. In addition to the fast-moving molecules, other effects are produced by the fire. These effects are known as *radiations*. We see some of these radiations as light and feel other radiations as heat. Any modern high school physics book will describe these radiations in detail.

§30. Expansion of solids due to heat A steel rod that measures exactly 10 feet in length at 100°F will measure 10.07 feet in length at 1000°F. The rod expands and gets longer as it is heated from 100 to 1000°F. The reason for this is that as the material becomes hotter, the molecules move faster and faster. If the steel is heated enough, it will melt. But even before this happens, the steel expands a little. This is because as the molecules move faster and faster, they must have more room. They "push" adjacent molecules away, so that all molecules, in effect, spread out, and expansion takes place.

§31. Expansion of liquids and gases due to heat Liquids and gases also tend to expand when heated. A cubic foot of water at 39°F will increase in volume to 1.01 cubic feet when heated to 100°F. If you had a cubic foot of air at 32°F and increased its temperature to 100°F, holding the pressure constant, you would find that its volume had increased to 1.14 cubic feet. These expansion effects result from more rapid molecular motion that tends to push the molecules farther apart so that they spread out and take up more room.

§32. Increase of pressure with temperature You get a different effect if you hold the volume constant while the cubic foot of air is heated from 32 to 100°F. If we started with a pressure of 15

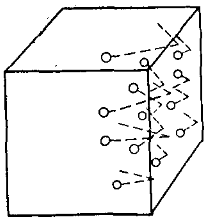


FIG. 2-8. Gas pressure in a container is the result of unending bombardment of the inner sides of the container by the fast-moving molecules of gas. This bombardment is shown on one side only of the container for simplicity. It actually takes place against all the inner sides. The molecules are shown tremendously enlarged. There are, of course, almost countless billions of molecules in action, and not a few as shown.

psi (pounds per square inch), we would find that the pressure had increased to about 17 psi at 100°F. This is further evidence of the molecular nature of heat. Actually, the pressure is due to the endless bombardment of the sides of the container by the fast-moving molecules of air or gas in the container (Fig. 2-8). Of course, a few molecules bumping against the sides of the container would show little effect. However, since there are billions upon billions of molecules bumping the walls, their combined "bumps" add up to a definite "push," or pressure.

As temperature increases, the molecules of air are moving faster. They bump the walls of the container harder and more often, thus registering a stronger "push," or greater pressure.

In a similar way, when the molecules are pushed closer together (that is, when the air in the container is compressed), the molecules bump into each other and into the walls of the container more often. This more intense bombardment corresponds to a greater pressure.

§33. Gravity Let us get away from molecules for a moment and talk about gravity. Gravity causes the stone we drop to fall to the earth. It makes the rain fall and the automobile coast down the hill. Conversely, it makes you work harder when you climb stairs and makes the engine work harder when pulling the car up a hill. Gravity is the attractive force between all objects. We normally measure gravity in terms of *weight*. When we put an object on a scales and note that it "weighs" 10 pounds, we are actually saying that the object has sufficient *mass* for the earth to register that much pull on it. If the object had twice as much mass, then the pull, or weight, would be 20 pounds.

§34. Atmospheric pressure We do not usually think of the air around us, our atmosphere, as having any weight. But since it is a substance (composed of gas molecules) and since the earth attracts it (or attracts each molecule), it does have weight. At sea level, and at average temperature, a cubic foot of air weighs about 1¼ ounces (or 0.08 pound). This does not seem like very much. But when you consider that the atmosphere (the blanket of air surrounding the earth) extends upward many miles, you can see that the total effect is large. For there are, in effect, thousands upon thousands of cubic feet of air, piled one on top of another, each adding its weight. This total weight, or downward push, amounts to about 15 psi (pounds per square inch) at sea level. This amounts to 2,160 pounds, or more than a ton, of pressure per square foot (2,000 pounds = 1 ton).

Atmospheric pressure is not constant. It changes with the weather. It also varies with height above sea level (on a mountain or in a plane). The higher you climb, the lower the pressure; there is less air above you to press down on you. At 30,000 feet above sea level, the air pressure is down to about 5 psi. At 100,000 feet altitude, the pressure is no more than 0.15 psi. The farther out from earth, the less air, and therefore less air pressure, there is. A few hundred miles from the earth's surface there is practically no air at all; there is simply a *vacuum.*

NOTE: During hot weather, the air expands and becomes lighter. This means the atmospheric pressure is reduced. Cooled air is heavier and increases atmospheric pressure. Varying air temperatures (due to the amount of heat the air gets from the sun) do more than cause changing atmospheric pressure. The lighter air rises; the heavier air sinks; and the varied movements of the air give rise to our changing weather.

§35. Vacuum As we mentioned in the previous section, absence of air or other material substance is called *vacuum.* We can create a partial vacuum on the earth, but our best vacuum is not so good as the vacuum far out in space, hundreds of billions of miles away from the earth. The automobile engine is in one sense a vacuum producer. Every time a piston moves down in a cylinder on the intake stroke, it produces a partial vacuum in the cylinder. As the piston moves down, it leaves "nothing" behind it. This "nothing" is the partial vacuum. Let us look at this from the standpoint of the molecules. We know that the air is made up of molecules or atoms of various gases, moving about in all directions. When the piston moves down, the gas molecules in the upper part of the cylinder are given more room to move around in. They spread out to occupy more or less uniformly the increasing space (as piston moves down). Actually, what this means is that the distance between the molecules increases. The greater the distance between molecules, the higher the vacuum.

As the vacuum increases in the cylinder (due to piston moving down), the atmospheric pressure outside the engine pushes air into the cylinder. This air moves through the carburetor and past the opened intake valve. Atmospheric pressure always tries to push air into any space where vacuum exists. Following sections explain how the air movement through the carburetor causes gasoline to be discharged into the air stream to produce a combustible air-fuel mixture.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

Once more, you will want to check up on how well you are remembering the material you have been reading. The questions that follow will help you check yourself so you will know whether you remember the facts discussed in the chapter you have just completed. In addition, since the questions are on the most important facts, they serve as a review of those facts. But don't be discouraged if you cannot answer all the questions offhand. Few people can remember everything they read, especially after reading it only once. If any of the questions stump you, just turn back into the chapter and reread the pages that will help you answer the questions.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will corrctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. A substance made up entirely of only one type of atom is called *a particle* *a molecule* *an element*
2. The three fundamental particles of which atoms are composed are *molecules, atoms, and electricity* *electrons, protons, and neutrons* *positives, negatives, and molecules*
3. In the chemical reaction known as *combustion*, each oxygen atom normally take on *1 electron* *2 electrons* *2 protons* *2 neutrons*
4. Since gasoline is made up essentially of hydrogen and carbon molecules, it is a *liquid* *gas* *hydrocarbon* *carbohydrogen*
5. Two of the products formed when gasoline burns are *oxygen and hydrocarbon* *carbon and oxygen* *water and carbon dioxide* *water and oxygen*
6. One way of looking at heat is to say that with increasing temperature, the *molecules move faster* *molecules move slower* *molecules vaporize*
7. As the temperature of the gas in a closed container is increased, the increasing speed with which the molecules are moving produces the effect of a *pressure increase* *pressure decrease* *pressure loss* *vacuum increase*
8. Atmospheric pressure is produced by the gravitational attraction of

the earth on the *vacuum* *air* *air pressure* *weight of air*

9. As air is heated, it *expands and becomes heavier* *expands and becomes lighter* *contracts and becomes heavier*
10. When there are relatively few molecules, widely scattered, the condition is called a *vacuum* *pressure of air* *pump action* *space*

SUGGESTIONS FOR FURTHER STUDY

If you are interested in the basic principles discussed in the chapter you have just finished, you might like to study them further. Almost any up-to-date high school physics book will give you much additional information on the principles covered in the past few pages. The *Automotive Engines* book (another book in the McGraw-Hill Automotive Mechanics Series) has additional explanations of the principles. Your local library probably has several physics books you will find of interest. In addition, if you have a chance, you could talk over various points that may not be clear to you with your local high school science or physics teacher. Teachers are almost always fine people who are sincerely interested in helping you gain more knowledge and thereby better yourself.

3: Fuel-system operation

THIS CHAPTER describes the operation of carburetor-type fuel systems. We have already noted that the automotive fuel system consists of the fuel tank, fuel gauge, fuel pump, carburetor, intake manifold, connecting fuel lines, and the accelerator pedal and linkage (Fig. 2-1). Now, in the pages that follow, the purpose and operation of each of these is described in detail.

§36. Fuel tank The fuel tank (Fig. 3-1) is usually located at the rear of the vehicle and is attached to the frame. It is a storage tank for fuel, made of sheet metal. It sometimes contains a number of baffles, or metal plates, attached to the inner surface of the tank, parallel to the ends. These plates have openings through which the fuel can pass. Their main purpose is to prevent sudden surging of

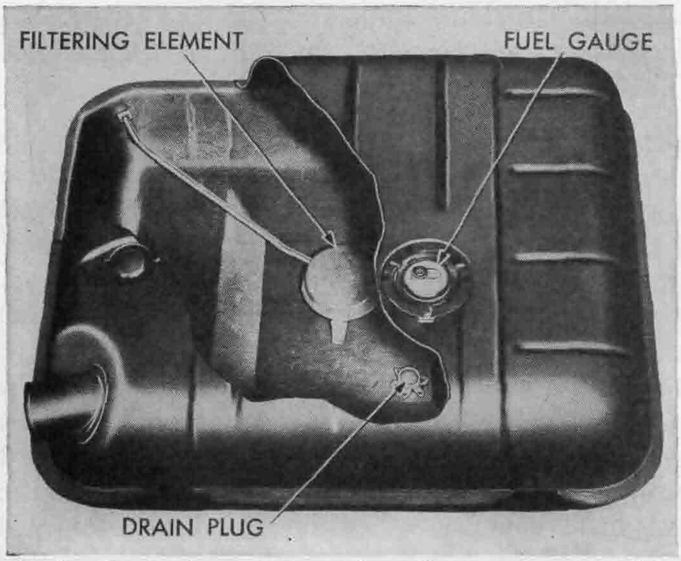


FIG. 3-1. Fuel tank, partly cut away to show filtering element and drain plug. (*Plymouth Division of Chrysler Corporation*)

the fuel from one end of the tank to the other when the car rounds a corner. The filler opening of the tank is closed by a cap, and the tank end of the fuel line is attached at or near the bottom of the tank. Usually, this line enters the tank at some point slightly above the bottom, so that dirt or water that has settled to the bottom of the tank will not enter the fuel line.

The fuel tank contains the tank unit of the fuel-gauge system (§38) and usually a filtering element of some kind to filter dirt from the fuel and prevent it from entering the fuel line. The filter is located at the point where the fuel line is attached to the tank; all fuel leaving the tank must pass through the filter. The fuel-tank cap has a vent which permits air to enter the tank as fuel is withdrawn. If this vent were to become stopped up, a vacuum would be created in the tank that would prevent normal delivery of fuel to the fuel pump and carburetor.

§**37. Fuel filters and screens** Fuel systems include filters and screens of various types to prevent dirt or grit in the fuel from entering the fuel pump or the carburetor. The fuel pump has valves that could be prevented from operating normally by particles of dirt, while the carburetor contains fuel passages and jets that could become clogged by dirt. In some systems the fuel filter is a separate unit located in the fuel line. In many systems a filter is incorporated in the fuel pump itself (see §39). In addition, the carburetor may contain filter screens.

§**38. Fuel gauge** Years ago, the standard procedure for finding out how much gasoline remained in the tank was to remove the tank cap and insert a measuring stick. Today, however, the driver merely looks at the gauge on the dash of the vehicle. Gasoline, or fuel, gauges can be divided into two general classifications, hydrostatic and electric. The hydrostatic fuel gauge, not in general use today, will be considered only briefly.

1. *Hydrostatic.* The hydrostatic fuel gauge depends upon the pressure of the fuel in the tank on a column of air. The column of air is contained in a vertical tube open at the end inserted in the fuel. The fuller the tank, the more pressure the fuel exerts on the column of air. The upper end of the air tube is connected to an indicating tube on the dash that is partly filled with colored liquid. Increased air pressure, caused by a full fuel tank, pushes the

colored liquid high in the indicating tube. As the fuel level drops, the air pressure decreases, allowing the colored liquid to drop to a lower level in the indicating tube. The air in the air tube in the tank is continually replenished by a splash cup near the top of the tank, into which gasoline is constantly splashed by the car movement. The gasoline drains back down into a tube attached to the splash cup, carrying with it air, which is released at the bottom of the air tube.

2. *Electric.* Electrically operated fuel gauges may be divided into two types, the balancing-coil type and the bimetal-thermostat type.

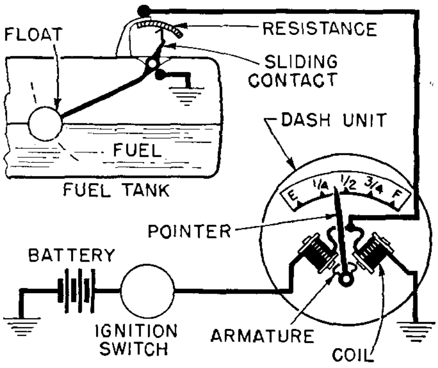


FIG. 3-2. Schematic wiring circuit of balancing-coil fuel-gauge indicating system.

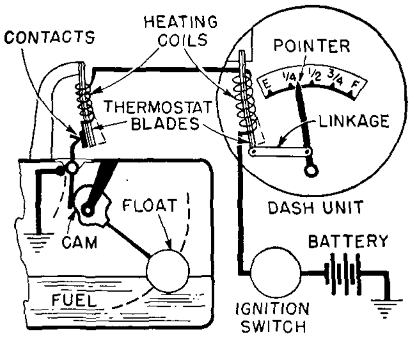


FIG. 3-3. Schematic wiring circuit of thermostatic fuel-gauge indicating system.

The balancing-coil type uses a variable resistance, or rheostat, in the tank and two coils of wire placed at a 90-degree angle to each other in the dash indicating unit (Fig. 3-2). The movement of a float up or down in the tank as the tank is filled or emptied causes a sliding contact to move around to various positions on the resistance. This allows the resistance to pass more or less electric current, passing more as the tank empties and less as the tank fills. As the tank empties, more and more of the electric current passing through the "empty" coil from the battery then flows through the resistance instead of through the "full" coil. Consequently, the magnetic strength of the "full" coil is weakened, allowing the armature to which the indicating needle is fastened to be pulled around by the magnetic force toward the "empty" coil. But when the tank is filled, the sliding contact moves around so that resistance is increased.

Most of the current passing through the "empty" coil then passes through the "full" coil. This produces a different magnetic pattern which turns the armature and needle toward the "full" coil. Note that the fuel-gauge indicator is connected to the battery through the ignition switch. This prevents any drain on the battery when the ignition switch is turned off and the engine is not running. More data on magnetism and resistance are contained in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Electrical Equipment*).

The bimetal-thermostat type of fuel gauge depends upon the heating and bending of two bimetal-thermostat blades, one in the tank unit and one in the dash indicating unit (Fig. 3-3). Each bimetal-thermostat blade consists of two strips of different metals, welded together. When heated, the two metals expand at different rates, causing the blade to bend. Around each blade is a heater wire. Both wires carry the same amount of current, and thus each blade is heated the same amount. Consequently, each blade will bend the same amount. When the tank is filled, a cam attached to the float in the tank moves a contact button that imposes an initial distortion on the tank-unit blade. This blade must then heat considerably before it bends enough to move away from the contact button. While it is heating, the blade in the dash unit also heats, bending so that the indicating needle is moved toward "full." When the tank-unit blade has bent enough to move away from the contact button, current stops flowing, and the blade cools and moves back to the button. Current again flows; the blade heats and bends away again. As the tank empties, the float drops and the cam moves around so that it imposes less initial distortion on the blade. Thus, the blade does not have to heat quite as much to bend further and move away from the contact button: less heating is required to keep the tank-unit blade vibrating and opening and closing the circuit. Consequently, the dash-unit blade is heated less and does not bend so much, so that the needle moves back toward "empty."

§39. Fuel pump Earlier fuel systems depended on gravity or air pressure to cause the flow of gasoline from the gasoline tank to the carburetor. In the gravity system the fuel tank had to be located above the carburetor, and the fuel ran down from the tank to the carburetor by force of gravity. It is no longer in common use because of its disadvantages, among which were the uncertainty of having enough fuel when climbing a hill and the fire hazard from the necessary closeness of the tank to the engine. The pressure system utilized an air pump that built up pressure within the fuel tank, forcing the fuel from the tank to the carburetor. This design also is no longer in common use because of the complexity of the system, which required two lines to the tank and a good tank seal.

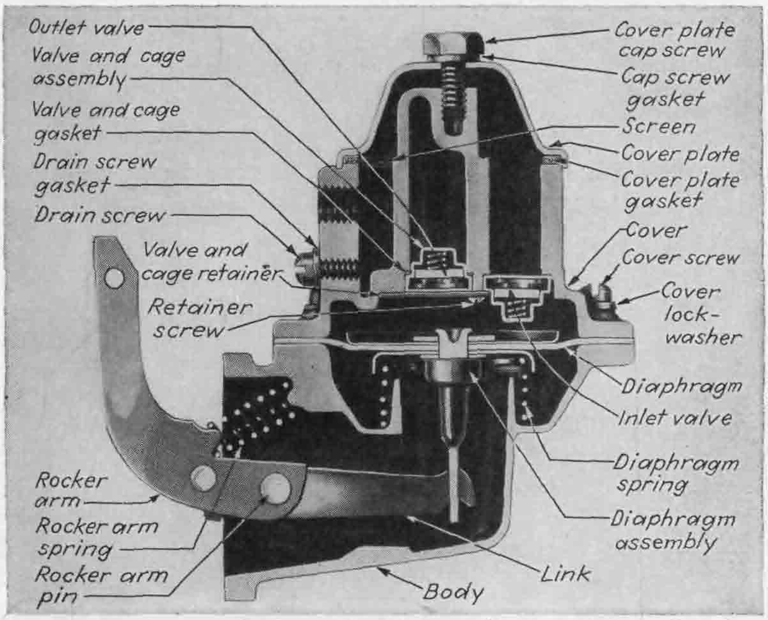


FIG. 3-4. Sectional view of a fuel pump. Inlet valve is to right and outlet valve to left. (*AC Spark Plug Division of General Motors Corporation*)

Modern fuel systems use a simple fuel pump (Figs. 3-4 and 3-5) to pump the fuel from the tank and deliver it to the carburetor.

The fuel pump is usually mounted to the side of the engine block, well down, to avoid excessive temperatures from the engine (Fig. 3-6). A rocker arm from the pump extends through an opening provided for it in the side of the engine block and rests against an eccentric (or offset ring) on the camshaft. Thus, when the camshaft rotates, the eccentric will cause the rocker arm to rock back and forth. A rocker-arm spring keeps the rocker arm in constant contact with the eccentric.

The rocker arm is linked to a diaphragm. The diaphragm is made of a special flexible clothlike material that is not affected by gasoline. It is fastened between two cuplike plates at its center. Its outer edge is clamped between the upper and lower parts of the pump. The diaphragm is spring-loaded so that it attempts to remain at its upper limit of travel. However, the movement of the rocker arm, acting through the link, pulls the diaphragm down. This movement tends to create vacuum in the fuel-pump chamber which is just above the diaphragm. As we have already noted (in

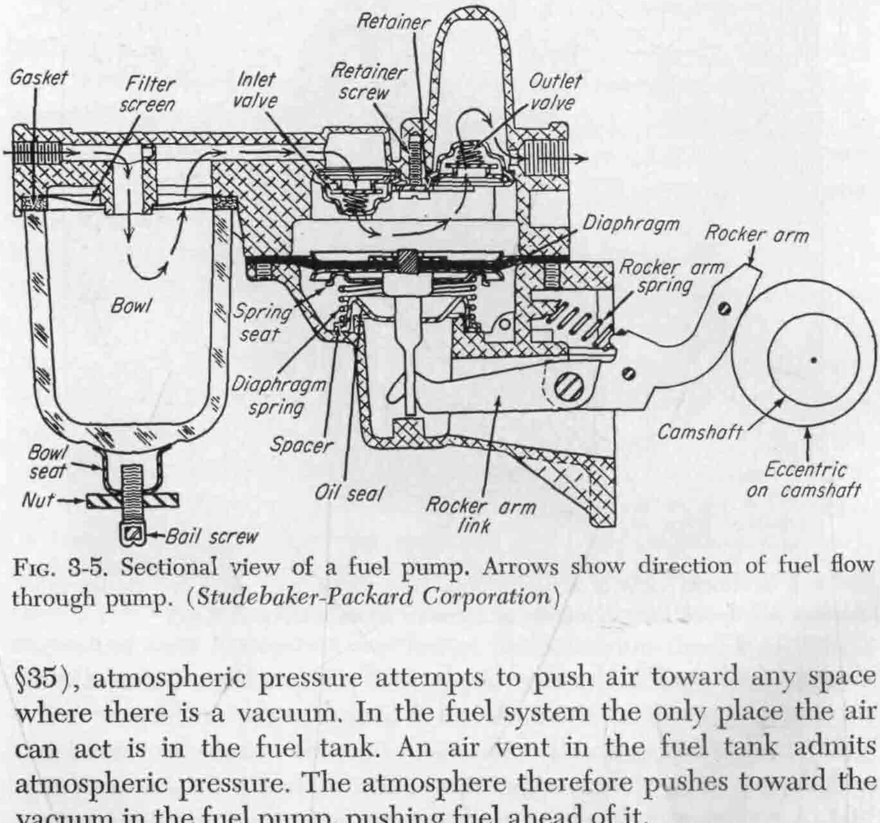


FIG. 3-5. Sectional view of a fuel pump. Arrows show direction of fuel flow through pump. (*Studebaker-Packard Corporation*)

§35), atmospheric pressure attempts to push air toward any space where there is a vacuum. In the fuel system the only place the air can act is in the fuel tank. An air vent in the fuel tank admits atmospheric pressure. The atmosphere therefore pushes toward the vacuum in the fuel pump, pushing fuel ahead of it.

As the fuel is pushed toward the vacuum created by the downward movement of the diaphragm, the inlet valve is forced down off its seat. Fuel therefore is pushed into the pump chamber (just above the diaphragm). Now, a moment later, as the camshaft revolves, the high area of the eccentric moves away from the rocker arm. The rocker arm therefore rocks toward the camshaft, releasing the diaphragm. The diaphragm is pushed upward by its spring. This produces a pressure of several pounds per square inch (psi) in the pump chamber. The pressure forces the inlet valve closed and forces the outlet valve open. Diaphragm-spring pressure then forces fuel through the outlet valve, through the connecting line, and into the carburetor.

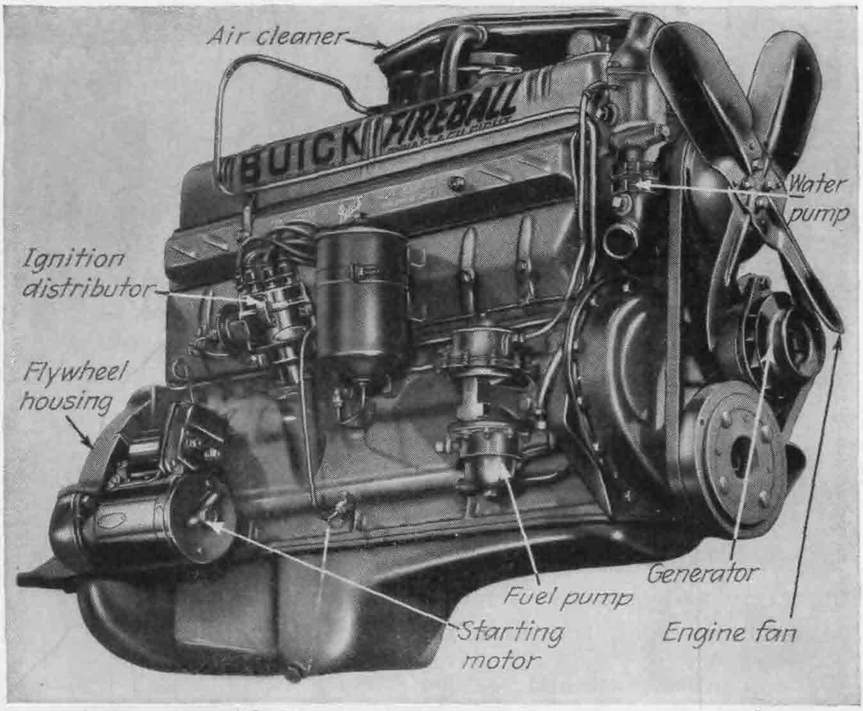


FIG. 3-6. Mounting of fuel pump on engine. Other accessories, including water pump, ignition distributor, starting motor, and generator are also shown. (*Buick Motor Division of General Motors Corporation*)

As will be explained in the section on carburetors, the fuel from the fuel pump is delivered to a float bowl, or reservoir, in the carburetor. The float bowl has a needle valve that shuts off the flow of fuel when the bowl is full. When this happens, the fuel pump stops delivering fuel to the float bowl. During this interval the rocker arm continues to rock. However, the diaphragm remains at or near the lower limit of its travel; its spring cannot force the diaphragm upward so long as the float bowl will not accept further fuel. However, as the carburetor uses up fuel, the needle valve in the float bowl opens to permit the fuel pump to deliver fuel. Now the diaphragm can move up (on the rocker-arm return stroke) to force fuel into the carburetor float bowl.

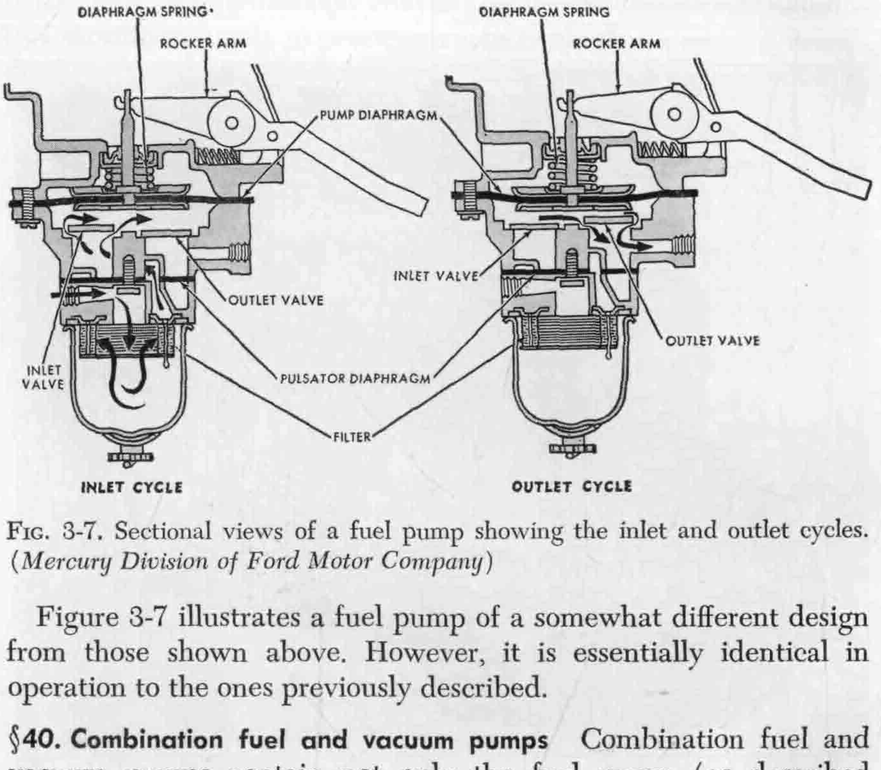


FIG. 3-7. Sectional views of a fuel pump showing the inlet and outlet cycles. (*Mercury Division of Ford Motor Company*)

Figure 3-7 illustrates a fuel pump of a somewhat different design from those shown above. However, it is essentially identical in operation to the ones previously described.

§40. Combination fuel and vacuum pumps Combination fuel and vacuum pumps contain not only the fuel pump (as described above) for supplying fuel to the carburetor, but also a vacuum pump that provides vacuum to operate the windshield wipers (Fig. 3-8). A majority of windshield wipers are designed to operate on vacuum. Many obtain their source of vacuum from the intake manifold. However, since intake-manifold vacuum varies considerably with different operating conditions, there are times when the vacuum will not be sufficient to operate the windshield wipers. This is most noticeable when the throttle is suddenly opened, as for instance when accelerating to pass another car. During such moments, when clear vision is most needed, the reduction in vacuum (due to opening the throttle) may cause the windshield wipers almost to stop. The vacuum pump (which is combined with the fuel pump) provides a steadier source of vacuum and more even operation of the windshield wipers.

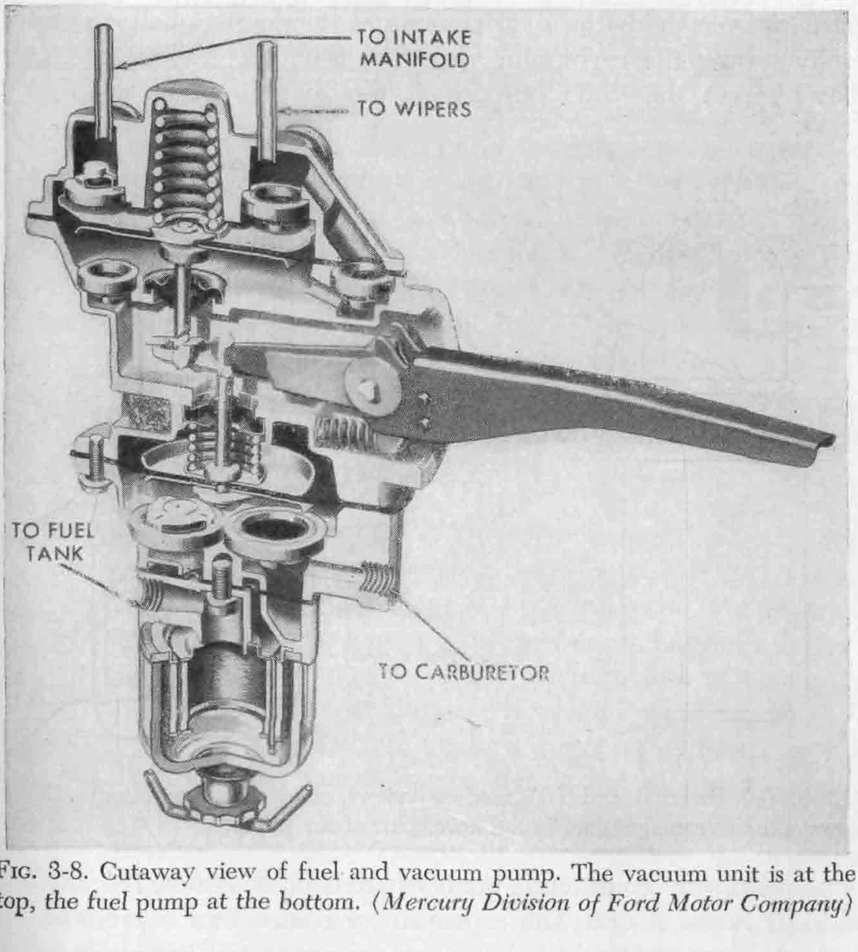


FIG. 3-8. Cutaway view of fuel and vacuum pump. The vacuum unit is at the top, the fuel pump at the bottom. (*Mercury Division of Ford Motor Company*)

In the combination pump shown in Fig. 3-8, the lower part is the fuel pump, which operates as already explained, and the upper part is the vacuum pump. You will note that it is very similar in appearance to the fuel pump. It contains a diaphragm actuated by a second link from the rocker arm, and two valves. The diaphragm and valves operate in the same manner as those in the fuel pump. The essential difference is that the vacuum pump pumps air instead of fuel. Air is pumped out of the windshield-wiper motor, producing the vacuum that causes the windshield wiper to operate.

§41. Electric fuel pumps The electric fuel pump (Fig. 3-9) found on some heavy-duty equipment, such as trucks and busses, uses electricity from the battery (or generator) to operate a bellows and thereby supply the carburetor with fuel from the fuel tank. The bellows serves the same purpose as the diaphragm in the fuel

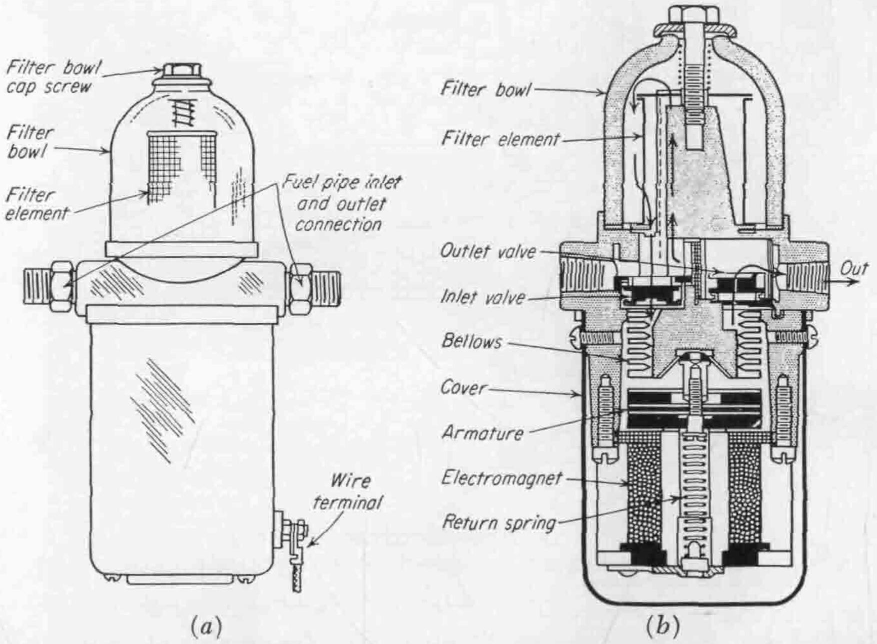


FIG. 3-9. (*a*) External and (*b*) sectional views of electric fuel pump. The bellows and electromagnet are in the lower part of the pump.

pumps previously considered. As it expands or collapses, it "pulls" fuel in or forces it out. The expansion or contraction is produced by an electromagnet which is repeatedly connected to or disconnected from the battery. The electromagnet becomes connected to the battery when the ignition switch is turned on. When this happens, the electromagnet is energized. This draws the electromagnet armature downward so that the bellows expands and produces a vacuum that causes fuel to pass from the fuel tank to the fuel pump. The inlet valve opens to permit the fuel to enter. As the armature reaches the lower limit of its travel, it opens contact points which open the circuit to the battery. The electromagnet therefore becomes disconnected and de-energized.

Now, the pump return spring pushes upward on the armature and bellows, collapsing the bellows and forcing the fuel in the bellows out through the outlet valve. As this happens, the inlet valve is forced closed. The fuel passes from the fuel pump to the carburetor. As soon as the armature reaches the upper limit of its travel, it closes the contact points so that the electromagnet is reconnected to the battery, and the above cycle is repeated. This action continues as long as the ignition system is turned on. The frequency with which the delivery stroke of the armature is repeated depends upon the amount of fuel the carburetor and engine require. When the engine is not using a great deal of fuel, the return spring collapses the bellows slowly since the needle valve in the carburetor is preventing rapid delivery of fuel to the carburetor. But when larger amounts of fuel are required, the bellows collapses more rapidly, and the delivery stroke is therefore repeated more often, to keep the carburetor supplied with fuel.

§42. Air cleaner A great deal of air passes through an engine when it is operating. As has already been mentioned, the fuel is mixed with air in the carburetor and the mixture passes on into the engine cylinders where it is ignited and burns. During normal running of the engine, the carburetor supplies a mixture ratio of about 15:1, that is, 15 pounds of air for each pound of gasoline. To say it another way, each gallon of gasoline requires as much as 1,200 cubic feet of air for normal combustion in the engine. As much as 100,000 cubic feet of air may pass through the engine every 1,000 car miles. This is a great volume of air, and it is apt to contain large quantities of floating dust and grit. Since this dirt and grit could cause serious damage to the engine parts if allowed to enter the cylinders, an air cleaner is used to filter such particles from the air. The air cleaner is mounted on the atmospheric side of the carburetor air horn. It consists of a large drum, the upper part of which contains a ring of noninflammable filter material (fine-mesh metal threads, or ribbons) through which the air must pass. This material provides a fine maze that filters out the dust particles (Fig. 3-10). An oil-bath air cleaner is shown in Fig. 3-10, while a heavy-duty horizontal cleaner is shown in Fig. 3-11. The oil-bath

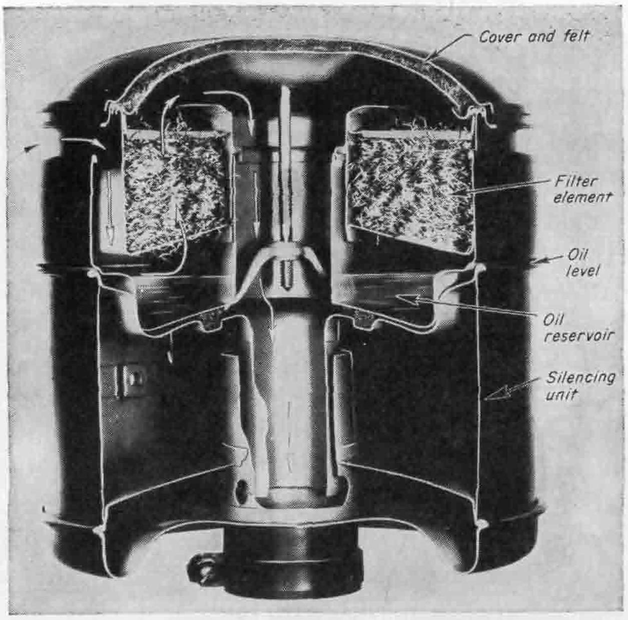


FIG. 3-10. Carburetor air cleaner and intake silencer of the oil-bath type. It incorporates an oil reservoir past which the air must flow. The sharp turn that the air must take throws particles of oil from the oil bath up into the filter. Dust that accumulates in the filter material is washed down into the oil reservoir by the oil. (*Oldsmobile Division of General Motors Corporation*)

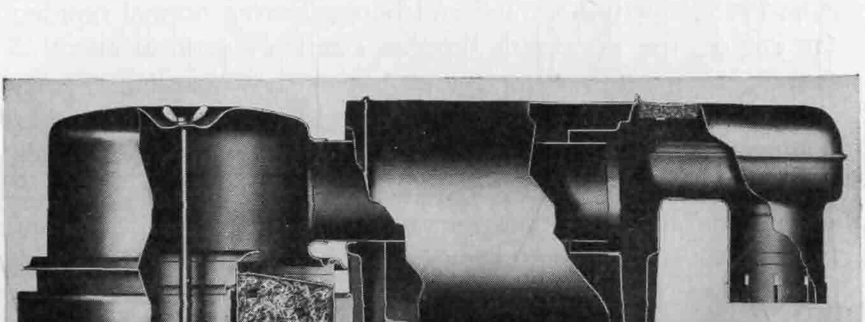


FIG. 3-11. Air cleaner for an eight-cylinder engine. The space limitations under the hood make is necessary to use a partly horizontal cleaner on this application. (*Oldsmobile Division of General Motors Corporation*)

cleaner contains a reservoir of oil past which the air flows. The moving air picks up particles of oil and carries them into the filter. There the oil washes accumulated dust and dirt back down into the oil reservoir. In addition to this washing action, the oiliness of the filter material improves the filtering action.

The air cleaner has a second function; it muffles the noise resulting from the intake of air through the carburetor and intake manifold and past the intake valves. Without the air cleaner, the sound of the intake of air could become quite noticeable and annoying to the driver.

The air cleaner also acts as a flame arrester in case the engine backfires through the carburetor. Backfiring may occur at certain times as a result of ignition of the air-fuel charge in the cylinder before the intake valve closes. When this happens, there is a momentary flash-back through the intake manifold and carburetor. The air cleaner prevents the flame from erupting from the carburetor and possibly igniting fuel or gasoline fumes on the outside of the carburetor.

§43. Intake manifold The intake ports in the side of the engine block (or in the side of the head on overhead-valve engines) are

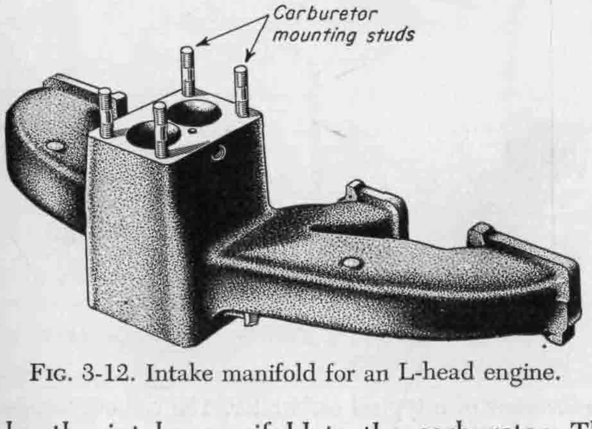


FIG. 3-12. Intake manifold for an L-head engine.

connected by the intake manifold to the carburetor. The air-fuel mixture from the carburetor passes through the intake manifold to the intake ports and through these ports to the engine cylinders (when the intake valves are open). Figure 3-12 shows a typical intake manifold for an L-head engine. Essentially, the intake manifold is nothing more than a series of passages leading from a central point (where the carburetor mounts) to the intake ports in the engine. The intake manifold is so designed as to aid in even distribution of the air-fuel mixture to the engine cylinders. In the design, sharp corners are avoided. Sharp corners might set up eddy currents which could result in uneven mixture distribution; some cylinders might be "starved."

§44. Carburetor The carburetor (Fig. 3-13) mixes air and gasoline in varying proportions for different operating conditions. As air passes through the carburetor on its way to the engine, gasoline is

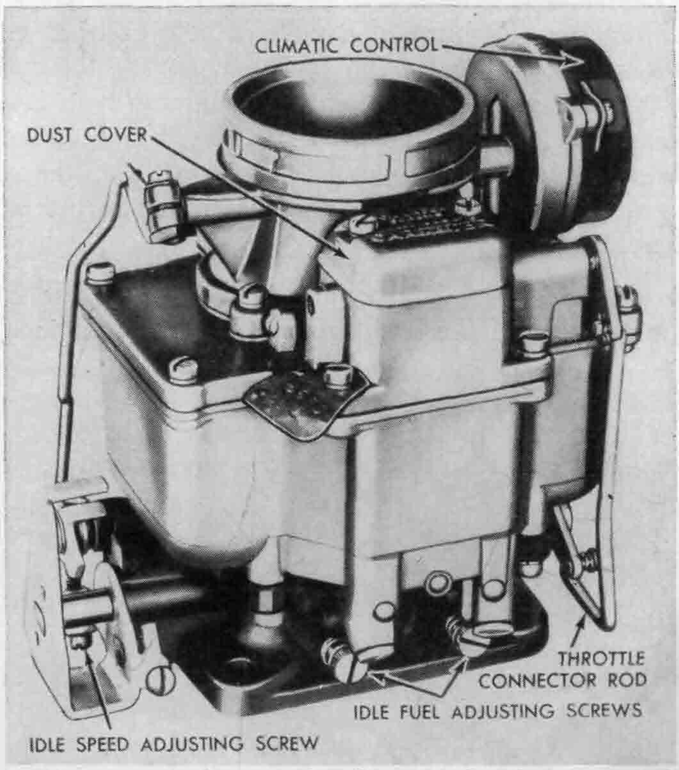


Fig. 3-13. Exterior view of a typical carburetor. The climatic control (at top) is the automatic choke.

fed into it through various circuits to be described below. The gasoline is fed into the passing air as a fine spray; that is, it is *atomized*. This causes the gasoline to evaporate very quickly, producing a combustible mixture of gasoline vapor and air.

§45. Evaporation When a liquid changes to a vapor (or undergoes a change of state) it is said to evaporate. Everyone is familiar with evaporation. Water placed in an open pan will eventually disappear; it changes from a liquid to a vapor. Clothes are hung on a line to dry; the water in the clothes changes to a vapor. When the clothes are well spread out, they will dry more rapidly than when they are hung closely or bunched together. This illustrates another well-known fact about evaporation. The greater the surface exposed to the air, the more rapidly evaporation will take place. If a pint of water is placed in a tall glass, it will take a long time to evaporate. But if a pint of water is placed in a shallow pan, the length of time required for the water to evaporate will be greatly shortened (Fig. 3-14).

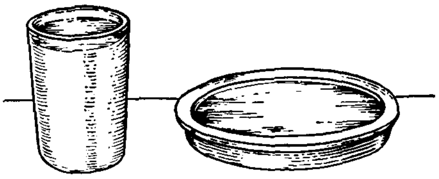


FIG. 3-14. Water will evaporate from the shallow pan faster than from the glass: the greater the area exposed to air, the faster the evaporation.

§46. Atomization Some early experimenters with gasoline engines tried to charge the ingoing air with gasoline vapor by passing it over pans of gasoline. This did not work very well because the pans could not be made large enough to expose a sufficiently large surface area of gasoline. The resulting mixture was too lean; it had too small a percentage of gasoline vapor in it. Then it was found that if the gasoline were sprayed into the passing air, adequate vaporization would take place. Whenever a liquid is sprayed, it is turned into a great many tiny droplets. This effect is called *atomization* because the liquid is broken up into small droplets (but not actually broken up into atoms as the name implies). Each droplet is exposed to air on all sides so that it evaporates, or turns to vapor, quickly. It is possible that an ounce of gasoline, broken up into fine droplets by spraying, will actually expose several square feet of surface area to air. Consequently, vaporization, or evaporation, takes place almost instantaneously.

§47. Carburetor fundamentals A simple carburetor could be made from a round cylinder with a constricted section, a fuel nozzle or tube, and a round disk, or valve, which could be tilted more or less to open or close the round cylinder (Fig. 3-15). The round cylinder is called the *air horn,* the constricted section the *venturi,* and the valve the *throttle* valve. Figure 3-16 shows the throttle valve in the closed position, the position at which it throttles, or shuts off, the air flow through the air horn so that little air can get through. The opened position is shown dotted. In the opened position, the valve has little throttling effect; air can flow through the air horn freely.

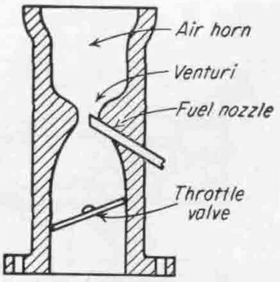


FIG. 3-15. Simple carburetor consisting of air horn, fuel nozzle, and throttle valve.

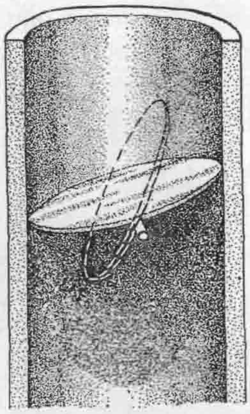


FIG. 3-16. Throttle valve in air horn of carburetor. When throttle is closed, as shown, little air can pass through. But when throttle is opened (as shown dotted), there is little throttling effect.

1. Venturi effect. As air flows through, a partial vacuum is produced at the constriction, or venturi. This vacuum causes the fuel nozzle to deliver gasoline into the passing air. Let us examine these actions more closely. The venturi effect (of producing a vacuum) can be illustrated by the setup shown in Fig. 3-17. In this illustration, three dishes of mercury (a very heavy metallic liquid) are connected by tubes to an air horn with a venturi. The greater the vacuum, the higher the mercury is pushed up in the tube by the atmospheric pressure acting on the surface of the mercury in each dish. Note that as air flows through the venturi, the greatest amount of vacuum is produced in the venturi. This vacuum increases with the speed of the air flowing through the venturi.

The air is not a continuous fluid, or substance; it consists of separate particles, or molecules. When we keep this in mind, the venturi effect becomes more easily understood. For example, let us follow two particles through the venturi and see what happens. As air enters the top of the air horn, all the air particles are moving downward toward the venturi at more or less uniform speed. However, if all particles are to move through the constriction, or venturi, they will have to speed up and hurry through. Suppose we watch

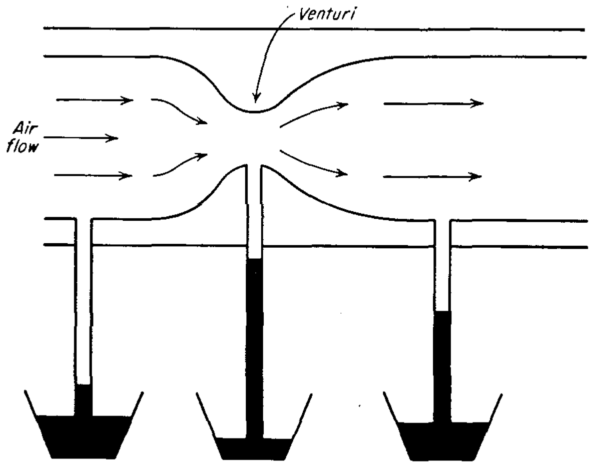


FIG. 3-17. Three dishes of mercury and tubes connected to air horn show differences in vacuum by the distance mercury rises in tubes. Venturi has highest vacuum.

two of the particles on their way through the venturi. One particle is somewhat behind the other. The leading particle, entering the venturi first, speeds up, tending to leave the second particle behind. The second particle, entering the venturi, also increases in speed. But the first particle has, in effect, a head start. The second particle cannot catch up. They are farther apart in passing through the venturi than they were when entering the air horn. Now visualize a great number of particles going through this same action, and you can understand that in the venturi they are somewhat farther apart than they were when they first entered the air horn. This is just another way of saying that a partial vacuum exists in the venturi. For, as we mentioned previously (§35), a partial vacuum is a thinning out of the air, a more than normal distance between the air particles, or molecules.

2. *Fuel-nozzle action.* The partial vacuum occurs in the venturi, where the open end of the fuel nozzle is placed. The other end of the fuel nozzle is in a fuel reservoir (the float bowl) on the side of the carburetor (Fig. 3-18). With a vacuum at the upper end of the fuel nozzle, atmospheric pressure (working through a vent in the float-bowl cover) pushes from the fuel reservoir up through the nozzle and out into the passing air stream. The fuel leaves the fuel nozzle in the form of a fine spray which rapidly turns into vapor as the droplets of fuel evaporate. The more air that moves through, the faster it moves and the greater the amount of fuel the

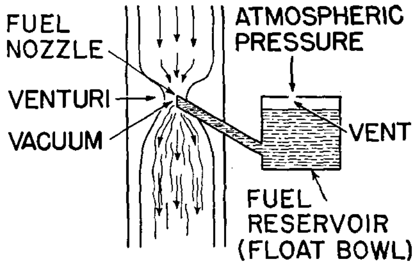


FIG. 3-18. The venturi, or constriction, causes a vacuum to develop in the air stream just below the constriction. Then atmospheric pressure pushes fuel up and out the fuel nozzle.

nozzle delivers (because higher air speed means a higher vacuum in the venturi).

Fuel-nozzle action might be compared to drinking through a straw. When you stop at the soda fountain and get a soda, you put the straw in your mouth and "suck" on it. Actually, you create a partial vacuum in your mouth by jaw and tongue movement. Atmospheric pressure then cooperates by pushing the liquid up through the straw and into your mouth. In the same way, atmospheric pressure pushes fuel from the float bowl, or reservoir, up through the fuel nozzle and into the vacuum of the venturi.

3. *Throttle-valve action.* As has already been mentioned, the throttle valve can be tilted in the air horn to allow more or less air to flow through. The throttle valve is a round disk mounted on a throttle shaft. The shaft can be rotated to tilt the throttle valve. When it is tilted to the position shown dotted in Fig. 3-16, a great deal of air can flow through. This produces a relatively high vacuum in the venturi, and a great deal of fuel is delivered to the

passing air. When large amounts of air-fuel mixture are fed to the engine, the engine develops a relatively high power output. This means that the car tends to speed up, or accelerate. Linkage between the throttle shaft in the carburetor and the accelerator pedal

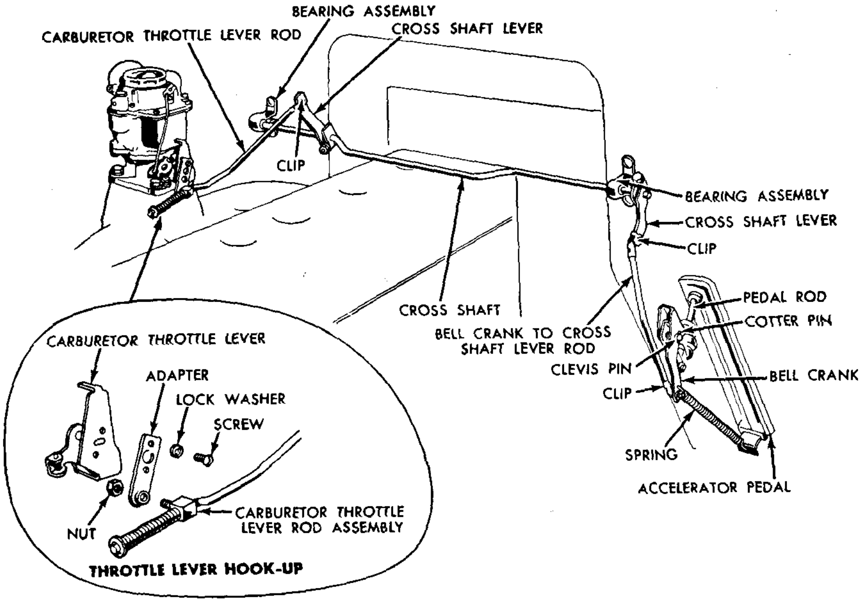


FIG. 3-19. Linkage between accelerator pedal and carburetor throttle valve.

in the driver's compartment for one car is shown in Fig. 3-19. The linkage differs for different cars.

§48. Float bowl The float bowl serves as a constant-level fuel reservoir. It is necessary for the fuel level in the float bowl to remain at a constant height, regardless of whether small amounts or large amounts of fuel are being withdrawn. If the fuel level goes too high, more fuel will be discharged through the fuel nozzle. On the other hand, if the fuel level is too low, less fuel will be discharged. In either case, the proportions of fuel and air would not be correct, and the engine would not operate properly.

To maintain the fuel level at a constant height, the float bowl contains a float pivoted on an arm, and a needle valve and seat. The needle valve is located at the inlet to the float bowl. Figure

3-20 is a simplified drawing of a float bowl, while Fig. 3-21 is a sectional view of an actual carburetor and float system. When the engine is running, the fuel pump supplies fuel to the carburetor, and the fuel flows through the inlet into the float bowl. If gasoline

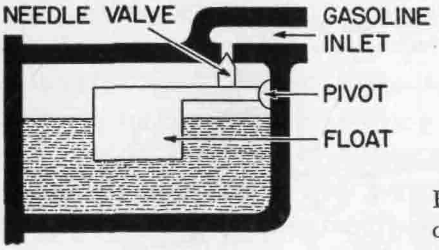


FIG. 3-20. Simplified drawing of a carburetor float system.

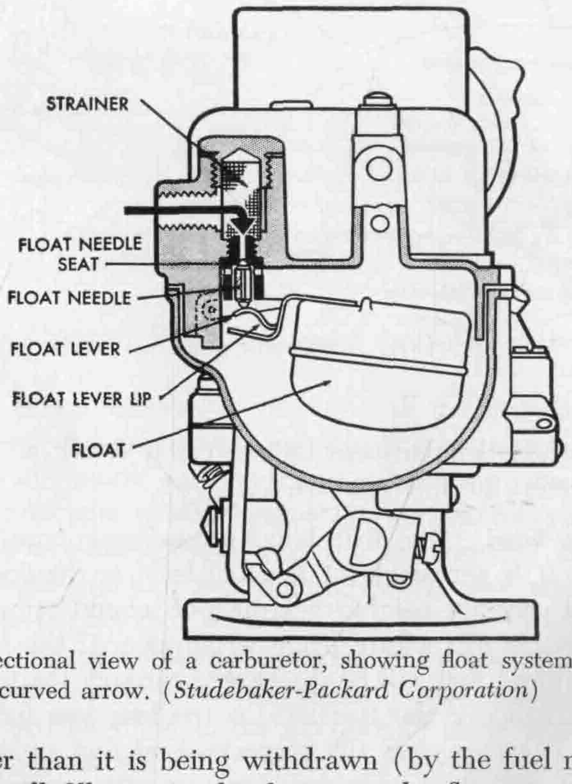


FIG. 3-21. Sectional view of a carburetor, showing float system. Fuel enters as shown by curved arrow. (*Studebaker-Packard Corporation*)

enters faster than it is being withdrawn (by the fuel nozzle), the float bowl will fill up. As this happens, the float rises, lifting the needle valve and forcing it tightly up into the needle-valve seat. This closes off the inlet, preventing further delivery of fuel. But as soon as some fuel is withdrawn, the fuel level falls, the float drops down, the needle valve is lowered off its seat, and additional fuel is delivered by the fuel pump. In actual operation, the fuel is maintained at a practically constant level in the float bowl. The float tends to hold the needle valve partly closed so that the incoming fuel just balances the fuel being withdrawn.

§49. Exhaust system After the air-fuel mixture has been burned in the engine cylinders, it is exhausted from the cylinders as the

FIG. 3-22. Exhaust system of an engine. →

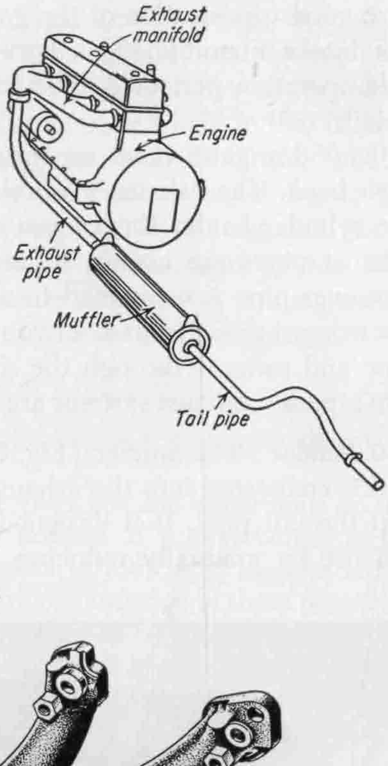
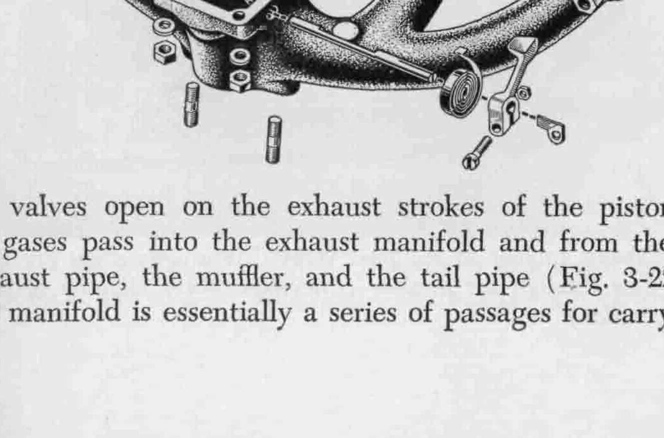


FIG. 3-23. Exhaust manifold for a six-cylinder L-head engine with heat-control valve and parts in disassembled view.



exhaust valves open on the exhaust strokes of the pistons. The burned gases pass into the exhaust manifold and from there into the exhaust pipe, the muffler, and the tail pipe (Fig. 3-22). The exhaust manifold is essentially a series of passages for carrying the exhaust gases from the engine cylinders to the exhaust pipe. A typical exhaust manifold is shown in Fig. 3-23. On L-head engines the exhaust manifold is bolted to the cylinder block. On I-head, or overhead-valve, engines the exhaust manifold is bolted to the cylinder head. The exhaust manifold is normally located under the intake manifold, and there is a connection between the two. The purpose of this connection is to supply heat to the intake manifold (from the hot exhaust gases) when the engine is first started, to assure good vaporization of the gasoline entering the engine through the intake manifold. This improves engine operation during the cold-operation period. A following section discusses this matter in detail.

On V-8 engines there are usually two exhaust manifolds, one on each bank. The exhaust manifolds are mounted on the outsides of the cylinder banks. Each has a separate exhaust pipe, but the two exhaust pipes are connected together into a crossover pipe. The crossover pipe is connected to a single muffler and tail pipe. Thus the exhaust gases from the two manifolds combine in the crossover pipe and exhaust through the same muffler. On some V-8 engines two separate exhaust systems are used (§51).

§50. Muffler The muffler (Fig. 3-24) is located under the car body and is connected into the exhaust system between the exhaust pipe and the tail pipe. It is designed to muffle the noise of the engine exhaust by gradually reducing the pressure of the exhaust gases

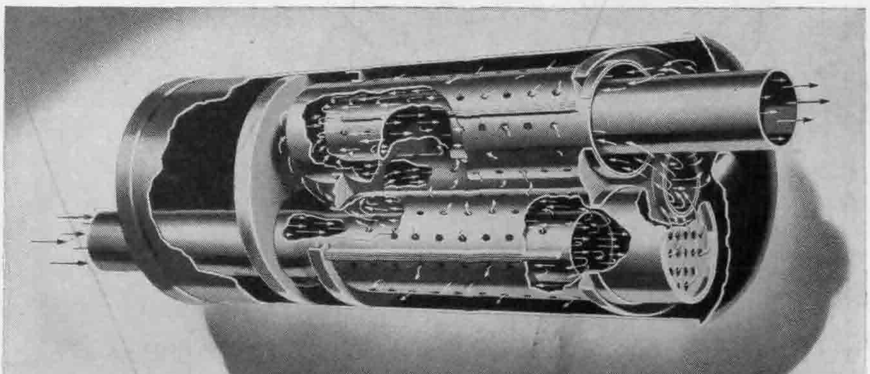


FIG. 3-24. Exhaust muffler in sectional view. The arrows show the path of exhaust-gas flow through the muffler. (*Chevrolet Motor Division of General Motors Corporation*)

as they leave the engine cylinders. Mufflers usually consist of a series of holes, passages, and resonance chambers that absorb and damp out the high-pressure surges introduced into the exhaust system when the exhaust valves open.

§51. Dual exhaust system The dual exhaust system used on one V-8 engine is shown in Fig. 3-25. Each exhaust manifold exhausts into a separate exhaust pipe which, in turn, exhausts into its own muffler, resonator, and tail pipe. The purpose of the resonators is to reduce exhaust noises further. They are, in effect, secondary mufflers. The use of two separate exhaust systems, one for each bank of cylinders, improves the ability of the engine to "breathe." That is, they allow the engine to exhaust more freely so that there is less exhaust gas left in the cylinders at the ends of the exhaust strokes. In other words, they lower the *back pressure* due to the restricting effect of the exhaust system. With less exhaust gas in the cylinders at the ends of the exhaust strokes, more air-fuel mixture can enter, and engine performance is improved. Adding a dual exhaust system can improve engine output several horsepower.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

Here is your chapter checkup that gives you the opportunity to test yourself on the chapter you have just finished. It is important to fix the fundamental principles of the fuel system in your mind because understanding of carburetor actions depends on knowledge of these principles. Thus, you will want to take the test below to determine whether you remember the principles. Don't be discouraged if you cannot answer all the questions. That simply means that you haven't quite fixed the facts in your mind. Thus, all you have to do is go back over the chapter so that you can get those facts memorized.

Unscrambling the Jobs

When the two lists below are unscrambled and combined, they will form a list of the various components of the fuel system and the jobs these components do. To unscramble the lists, take one item at a time from the list to the left, and then find the item from the list to the right that goes with it. Write the result down in your notebook. For example, the first item in the list to the left is "tank." When you look down the list to the right, you can see that the only item that describes the job the tank has

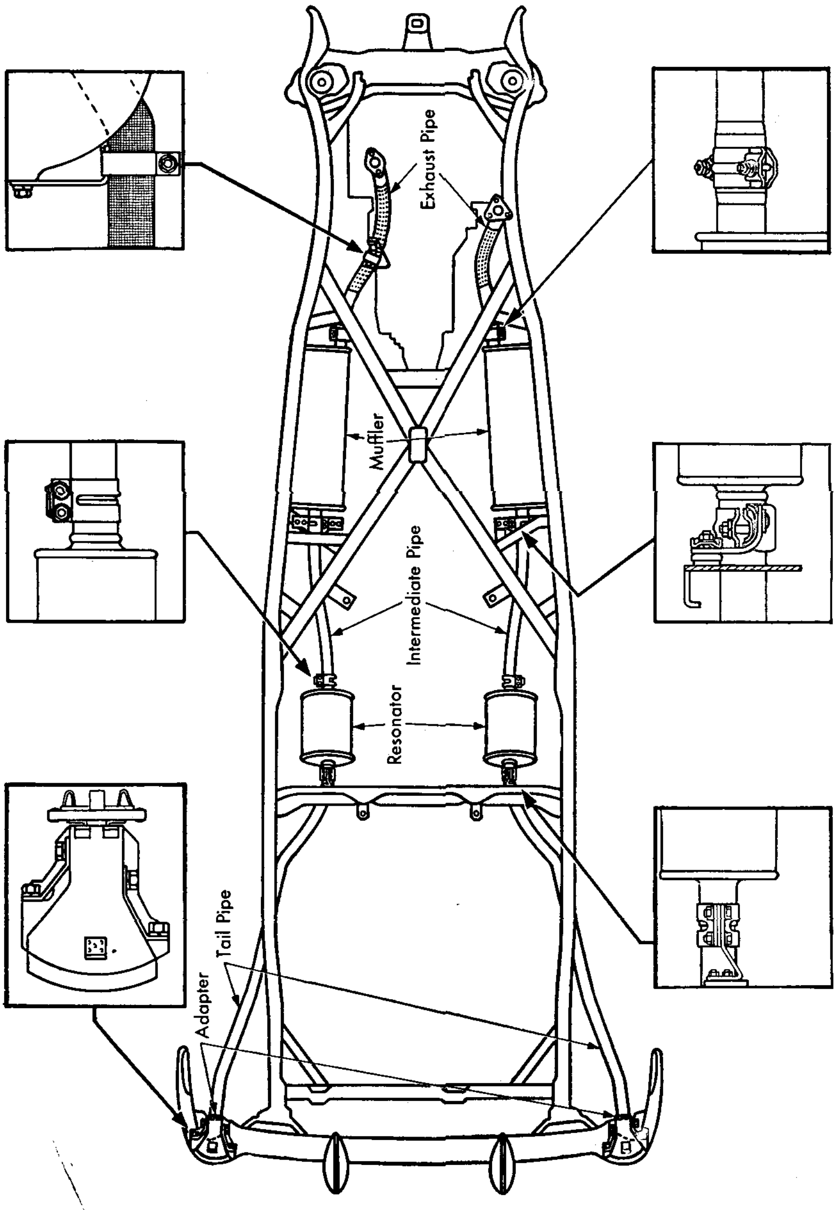


Fig. 3-25. Dual exhaust system used with one V-8 engine, showing various attaching and supporting brackets. (*Cadillac Motor Car Division of General Motors Corporation*)

to do is "stores fuel." So you put the two together to form "tank stores fuel."

tank	filters air
filter	mixes fuel and air
pump	stores fuel
carburetor	indicates fuel in tank
gauge	cleans fuel
air cleaner	delivers fuel to carburetor

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Electrically operated fuel gauges are of two types, *balancing-coil and hydrostatic* *bimetal-thermostat and hydrostatic* *balancing-coil and bimetal-thermostat*
2. The tank unit of the balancing-coil fuel gauge contains a *variable resistance* *bimetal thermostat* *switch* *capacitor*
3. The tank unit of the bimetal-thermostat fuel gauge has *a variable resistance* *a heating coil* *a pointer* *an armature*
4. In the fuel pump, the rocker arm, which rests against an eccentric on the camshaft, is linked to the *inlet valve* *outlet valve* *diaphragm*
5. Fuel is delivered from the fuel tank to the fuel pump as the rocker arm *pulls diaphragm down* *releases diaphragm* *closes inlet valve*
6. Fuel is delivered from the fuel pump to the carburetor by the *rocker-arm pull* *diaphragm-spring pressure* *float-bowl vacuum*
7. The device mounted on the carburetor air horn has two jobs, to *filter fuel and silence intake* *filter air and wash filter* *filter air and silence intake*
8. The breaking up of a liquid into fine droplets by spraying is called *vaporization* *atomization* *venturi effect* *carburetion*
9. A simple carburetor could be made from an air horn with venturi, a throttle valve, and *a float bowl* *throttle linkage* *a fuel nozzle*
10. The parts in the carburetor that permit or prevent fuel delivery, thus maintaining proper fuel level in the reservoir, include the *inlet and outlet valves* *fuel nozzle and venturi* *float and needle valve*

SUGGESTIONS FOR FURTHER STUDY

In any automotive shop offering fuel-system service, you will probably find worn-out fuel gauges and fuel pumps. Perhaps you will be permitted to examine these units and possibly to tear them down so you can inspect the internal parts. Examining the parts will help you understand the workings of the mechanisms. School automotive shops often have cutaway units that show the internal working parts clearly; these are very helpful to the student. *Automotive Electrical Equipment* (another book in the McGraw-Hill Automotive Mechanics Series) contains much additional material on electric fuel gauges and the principles on which they operate. Also, the manufacturers of the fuel-system components supply service manuals; if you can borrow these from your school automotive shop library or from a service shop, you will find them of great help. Be sure to write down in your notebook important facts you run across in the shop or when reading the manuals. This helps you remember the facts and also gives you a permanent record to which you can refer in case your memory gets hazy.

4: Carburetor fundamentals

THIS CHAPTER discusses carburetor fundamentals and describes the various circuits, or devices, in the carburetor which provide the proper air-fuel ratios for various operation conditions. The simple carburetor described in Chap. 3, "Fuel-System Operation," consisting of a venturi in an air horn, a fuel nozzle, and a throttle valve, could not supply the proper proportions of fuel for the wide variety of operating conditions typical of the automotive engine. For instance, during starting and initial warm-up, a rich mixture is required (high proportion of fuel). At operating temperatures and intermediate speeds, the mixture must be relatively lean (lower proportion of fuel). But when the engine is accelerated, or full power is demanded, then the mixture must be enriched.

§52. Air-fuel ratio requirements As we have said, the fuel system must vary the air-fuel ratio with different operating conditions. The mixture must be rich (high proportion of fuel) for starting and for idle, but must be relatively lean during part-throttle, intermediate-speed operation. Figure 4-1 is a graph showing typical air-fuel ratios as related to various car speeds. The car speeds at which these differing ratios are obtained vary with different cars. In the example shown, a rich mixture of about 9:1 (9 pounds of air for each pound of fuel) is supplied for initial starting. Then, during idle, the mixture leans out to about 12:1. At intermediate speeds, with the throttle partly opened, the mixture further leans out to about 15:1. But at higher speeds, with the throttle wide open, the mixture is enriched to about 13:1. Whenever the throttle is opened to accelerate the car, the mixture is momentarily enriched. This is accomplished by an accelerator pump in the carburetor which supplies additional fuel when the accelerator is moved toward the open position. Two examples of the enriching effect are shown (in dotted line) in Fig. 4-1. The first is at a little below 20 mph (miles per hour), when the driver opens the throttle to increase car speed. The second is at a speed of around 30 mph, when the car driver accelerates but does not keep the throttle wide open. Following sections describe the various parts of the carburetor that provide the different air-fuel ratios during car operation.

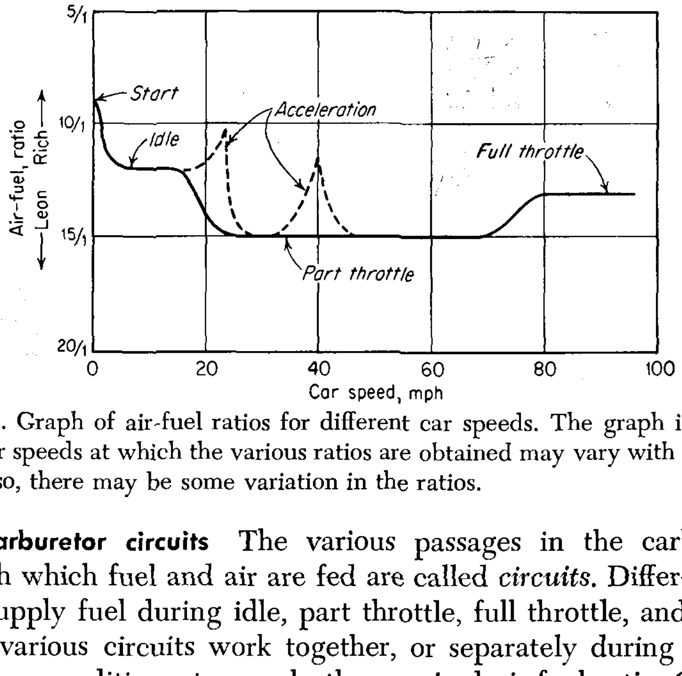


FIG. 4-1. Graph of air-fuel ratios for different car speeds. The graph is typical only; car speeds at which the various ratios are obtained may vary with different cars. Also, there may be some variation in the ratios.

§53. Carburetor circuits The various passages in the carburetor through which fuel and air are fed are called *circuits*. Different circuits supply fuel during idle, part throttle, full throttle, and so on. These various circuits work together, or separately during certain operating conditions, to supply the required air-fuel ratio. Circuits and mechanisms in the carburetor include

1. Float circuit
2. Idling-and-low-speed circuit
3. High-speed, part-load circuit
4. High-speed, full-power-circuit
5. Accelerator-pump circuit
6. Choke

These are discussed in detail on following pages.

§54. Float circuit We have already discussed the function of the float bowl, float, and needle valve (§48). Figure 3-21 shows a sectional view of a float circuit. When the fuel level in the float bowl drops, the float also drops, allowing the needle valve to move off the valve seat. This action allows the fuel pump to deliver additional fuel to the float bowl. As the fuel level rises, the float also rises. This lifts the needle valve up into the valve seat, shutting off the fuel flow into the float bowl. In actual operation, the float and needle valve move very little. They tend to take a position where the valve admits just enough fuel to balance fuel outgo.

§55. Concentric float bowls Many late-model carburetors have a "wrap-around" type of float bowl instead of having the float bowl located on one side of the carburetor air horn. The "wrap-around"

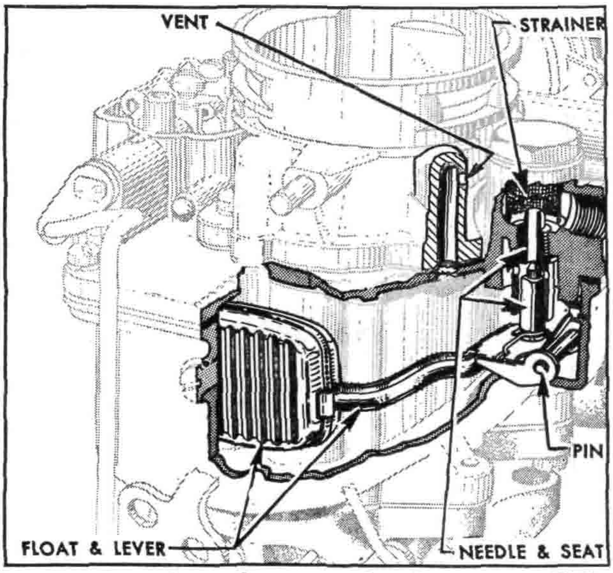


FIG. 4-2. Cutaway view of a carburetor with a "wrap-around" float bowl and dual-float assembly. (*Buick Motor Divivion of General Motors Corporation*)

float bowl partly or completely encircles the air horn, and a dual-float assembly is used, that is, one with two floats instead of one. Figure 4-2 is a cutaway view of a carburetor using this type of float assembly. Only one float is shown, the other float being located on the other side of the air horn. The two floats, fastened to the two ends of a U-shaped lever, work together to operate a single needle valve. The needle valve controls fuel delivery to the float bowl, as in other carburetors. Figure 4-3 shows a similar carburetor partly disassembled. In this view, both floats of the dual-float assembly can be seen. One of the advantages claimed for this type of float-bowl system is that it assures more uniform delivery of fuel to the engine. That is, even though the carburetor is tilted sharply one way or another (as it might be with the car on a bank or slope), the fuel level remains at the proper height with respect to the fuel nozzle. The fuel nozzle is close to the center of the float bowl; regardless of how the carburetor is tilted, the fuel level will stand

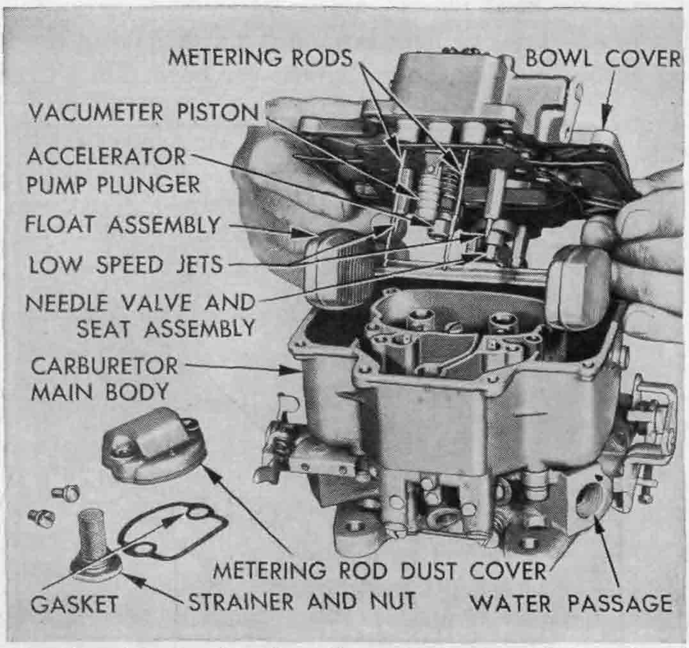


FIG. 4-3. Dual carburetor (two-barrel) partly disassembled so that the dual-float assembly can be seen. (*Chrysler Sales Division of Chrysler Corporation*)

at about the same height in the fuel nozzle. It is also suggested that the two floats tend to prevent flooding. When the carburetor is tilted the lower float bowl can act to close the needle valve even though the upper float is not supported by the fuel at all.

§56. Dual-float circuits Four-barrel carburetors (§90) are, in effect, two separate carburetors in a single assembly. One is a primary carburetor with the job of supplying air-fuel mixture under all operating conditions. The other is a secondary carburetor and has the job of supplying air-fuel mixture only at special times, as during high-speed, full-power operation. Each carburetor assembly has its own float-bowl circuit, consisting of a dual-float assembly, float bowl, and needle valve (Fig. 4-4). The fuel inlet from the fuel pump is located above the needle valve for the secondary carburetor float bowl. There is a fuel passage to the primary carburetor float bowl; this bowl has its own needle valve and float assembly. Note that the two float bowls are separated by a partition. However, there is a balance passage that connects between the two float bowls which assures equal fuel levels and air pressures in the two float bowls.

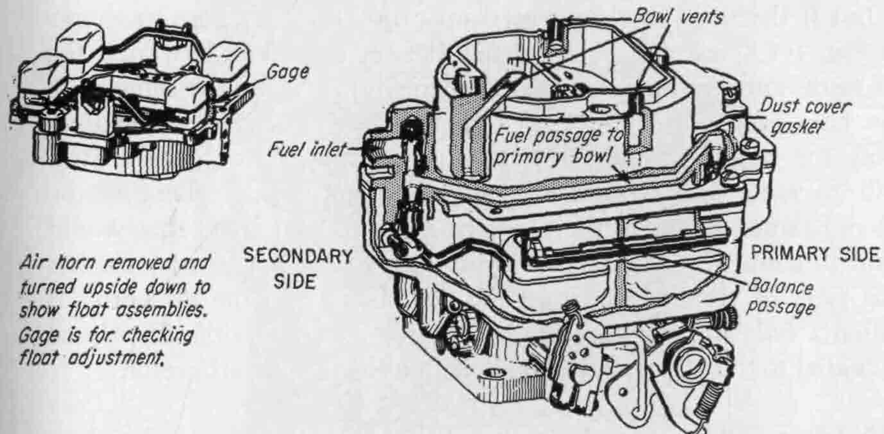


FIG. 4-4. Float system of four-barrel carburetor. (*Oldsmobile Division of General Motors Corporation*)

The primary float bowl supplies fuel to the two barrels of the primary carburetor. The secondary float bowl supplies fuel to the two barrels of the secondary carburetor. Section 90 covers four-barrel carburetors in detail.

§57. Float-bowl vents The float bowls of many carburetors are vented into the carburetor air horn at a point above the choke valves. The carburetor shown in Fig. 4-4 has the bowls vented in this manner. The purpose of this arrangement is to equalize the effect of a clogged air cleaner. To explain the advantage of this, let us first recall what we said in our discussion of carburetor fundamentals (§47) about the way atmospheric pressure acts through a vent in the float-bowl cover. When there is a vacuum in the venturi (at tip of fuel nozzle), atmospheric pressure pushes fuel from the float bowl up through the fuel nozzle and out into the passing air stream. However, with this system of venting the float bowl to the atmosphere, clogging of the air cleaner can change the air-fuel ratio delivered by the carburetor. Here's the reason for that.

If the air cleaner becomes clogged (as it does when it is not periodically cleaned), it restricts the passage of air into the carburetor air horn. When this happens, a partial vacuum is created in the air horn. This adds to and increases the vacuum at the fuel nozzle. As a result, the fuel nozzle will discharge more fuel. This may make the air-fuel mixture too rich.

But if the float bowl is vented into the upper air horn as shown in Fig. 4-4, there will be a balance between the float bowl and the air horn, and the air pressure in the air horn will be the same as in the float bowl. The effect of a clogged air cleaner is eliminated. *Only the vacuum produced by the air passing through the venturi* will cause the fuel to discharge from the fuel nozzle. There can be no unbalance between the air horn and the float bowl that would tend to cause the fuel nozzle to discharge fuel. A carburetor using this type of venting (venting the float bowl into the air horn) is called a *balanced* carburetor. A carburetor in which the float bowl is vented to the atmosphere is called an *unbalanced* carburetor.

§58. Idling-and-low-speed circuits When the throttle is closed or slightly open, only a small amount of air can pass through the air horn and flow around the throttle valve. The air speed is so low, and there is such a small amount of air passing through, that practically no vacuum develops in the venturi. This means that the fuel nozzle (centered in the venturi) will not feed any fuel during operation with a closed or only slightly opened throttle. For this reason, the carburetor must have another circuit to furnish air-fuel mixture during this type of operation. The idling-and-low-speed circuit does this job (Figs. 4-5 to 4-8).

The idling-and-low-speed circuit consists of a series of openings through which air and fuel can flow. With the throttle valve closed as shown in Fig. 4-5 and the engine idling, very little air can pass between the throttle valve and the air-horn wall, although some air does get through. Thus, a relatively high vacuum exists on the engine (or lower) side of the throttle valve. There is a small passage from the upper part of the air horn through the carburetor body to the idle adjustment screw. This passage is called the *idling-*

and-low-speed passage. Atmospheric pressure (in upper air horn) forces air through this passage (as shown by the lines in Fig. 4-5). Fuel also feeds into this passage from the float bowl as shown by the arrows. Atmospheric pressure causes this fuel flow; the fuel is pushed toward the vacuum below the throttle valve. The air and fuel mix as they move through the circuit toward the idle adjustment screw. The mixture is rich (has a high proportion of fuel).

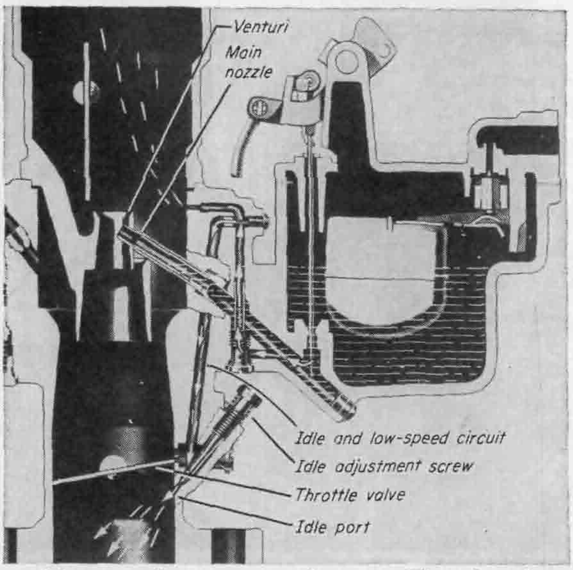


FIG. 4-5. Idle-and-low-speed circuit in carburetor. Throttle valve is fully closed, and all gasoline is being fed past the idle adjustment screw. Lines indicate air; arrows indicate gasoline. (*Chevrolet Motor Division of General Motors Corporation*)

It flows past the tapered point of the idle adjustment screw and down into the intake manifold. It mixes with the small amount of air that gets past the throttle valve to form a slightly leaner, but still satisfactorily rich, mixture. The mixture richness can be adjusted by turning the adjustment screw in or out. When it is turned in, less air-fuel mixture can pass through the circuit and the final mixture is leaner. When it is turned out, more air-fuel mixture can pass through and the final mixture is richer. Adjustment must be made so that the engine will be supplied with a correctly proportioned mixture for smooth idling.

§59. Low-speed operation When the throttle is opened slightly, as shown in Fig. 4-6, the edge of the valve moves past the low-speed port in the side of the carburetor air horn. This port is usually a vertical slot or a series of small holes one above the other. With the throttle valve only slightly opened, it is still impossible for sufficient air to pass through to produce a vacuum in the venturi. As a result, the main fuel nozzle still does not feed fuel. However, more fuel

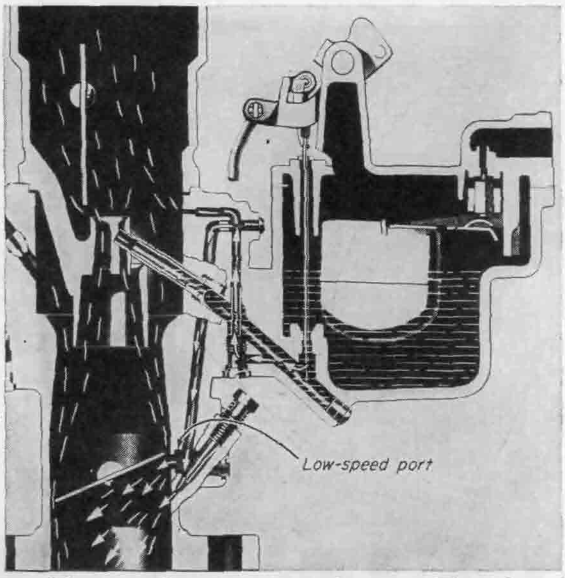


FIG. 4-6. Idle-and-low-speed circuit in carburetor. Throttle valve is slightly opened, and gasoline is being fed through low-speed port. Lines indicate air; arrows indicate gasoline. (*Chevrolet Motor Division of General Motors Corporation*)

is needed than can be supplied through the idle port (past the idle adjustment screw). The low-speed port supplies this additional fuel. As the edge of the throttle valve moves past the low-speed port, intake-manifold vacuum is applied to the port. Now, atmospheric pressure (pushing toward the vacuum) causes this port, as well as the idle port, to start discharging air-fuel mixture. This mixture is rich, but it is leaned out by the air passing the throttle valve. A satisfactory mixture is thus supplied for the operating condition. As the throttle is opened more, a larger part of the slotted port (or more of the drilled holes) is cleared and more air-fuel mixture is delivered.

§60. Other idle-and-low-speed circuits Figures 4-7 and 4-8 illustrate idle-and-low-speed circuits that are somewhat different from the circuit described above. Both, however, work in a similar manner. In Fig. 4-7, the fuel flows from the float bowl through the main metering jet and up through the idle tube. The idle tube has an opening of the proper size to allow the correct amount of fuel to pass through. As the fuel leaves the idle tube, it mixes with air entering through an air bleed (from the upper air horn). The mixture passes down around the idle-passage wire to the discharge ports. A secondary air bleed feeds additional air to the mixture just before it reaches the discharge ports. The two discharge ports work in the same way as those described above. That is, the lower port discharges air-fuel mixture during idle. Then, when the throttle is opened slightly, it moves past the upper, or low-speed, port so that it also begins to discharge air-fuel mixture.

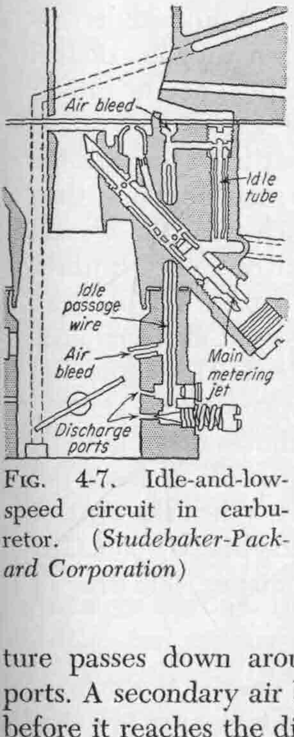


FIG. 4-7. Idle-and-low-speed circuit in carburetor. (*Studebaker-Packard Corporation*)

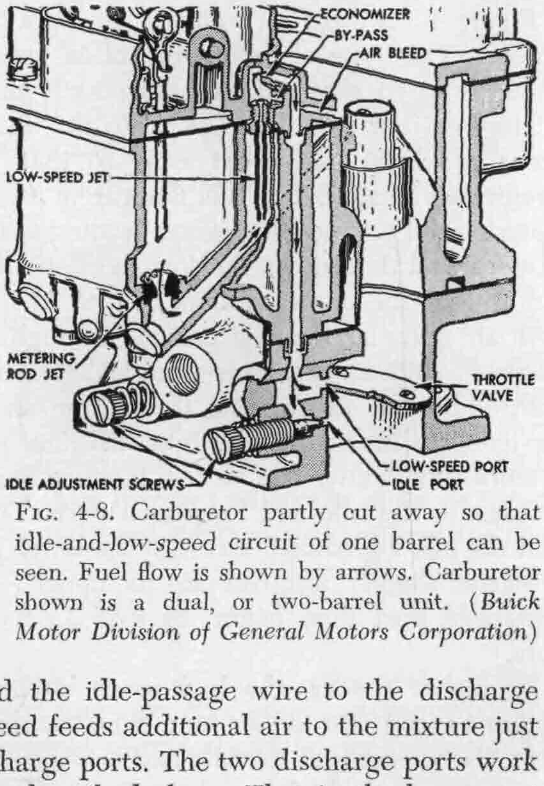


FIG. 4-8. Carburetor partly cut away so that idle-and-low-speed circuit of one barrel can be seen. Fuel flow is shown by arrows. Carburetor shown is a dual, or two-barrel unit. (*Buick Motor Division of General Motors Corporation*)

The lower, secondary air bleed (Fig. 4-7) has another function aside from bleeding air into the air-fuel mixture as it moves down the idle passage. At higher engine speeds, when the throttle is opened and the idle system is inoperative, the air bleed discharges a small quantity of fuel into the air stream going through the air horn. In other words, at higher speeds it works in reverse. Instead of bleeding air into the idle passage, it feeds fuel into the air horn. The fact that the air-bleed nozzle projects slightly into the air horn causes this latter action. The amount of air-fuel mixture fed into the air horn is small. But it is sufficient to keep the idle passage filled at all times. Then, when the throttle is suddenly closed, the idle circuit can take over instantly without the hesitation that might occur if the idle passage were not filled.

Figure 4-8 is a partial cutaway view of a dual, or two-barrel, carburetor. This type of carburetor, often used on eight-cylinder engines, has two separate air horns; each air horn supplies air-fuel mixture to four cylinders (§89). In the illustration, one of the air horns has been partly cut away so that the idle-and-low-speed circuit can be seen. The fuel flows from the float bowl through the metering-rod jet and the passage leading to the main nozzle. It then passes upward through the low-speed jet which is of the correct size to feed the proper amount of fuel. As it leaves the jet, it mixes with air entering the idle passage through a bypass. The mixture passes through an economizer, or drilled passage and then combines with additional air entering through an air bleed. This additional air tends to break the fuel into still finer particles, or to atomize it more completely. The air-fuel mixture then moves down the idle passage to the idle and low-speed ports. During idle, it feeds out past the idle adjustment screw in the lower port. When the throttle is opened slightly, it moves past the upper (or low-speed) port. The low-speed port then begins to feed air-fuel mixture into the air horn.

At higher speeds, the high-speed circuit takes over, and fuel begins to feed into the air horn from the main nozzle. As this happens, the vacuums at the idle and low-speed ports drop so low that they fade out; the high-speed circuit takes over completely.

A somewhat different type of idle circuit is shown in Fig. 5-14. In this carburetor the idle adjustment screw works in reverse from those previously discussed. In the unit shown in Fig. 5-14 the idle adjustment screw allows air to bleed into the idle circuit. Thus, as the idle adjustment screw is backed out, it will admit more air into the idle circuit, and the air-fuel mixture will be leaner. But when the idle adjustment screw is turned in, less air will be admitted into the idle circuit, and a richer mixture will be discharged from the idle port. The unit shown in Fig. 5-14 is an "updraft" carburetor (discussed in §87). However, this idle-adjustment-screw arrangement is used on both updraft and downdraft carburetors, as explained in §87.

NOTE: On many engines the ignition distributor has an advance mechanism which advances the spark under part-throttle conditions (see §82). With this system, the distributor is connected to the carburetor through a vacuum line (see Fig. 5-1). The vacuum line opens into holes or a slot cut in the carburetor air horn, approximately on a level with the low-speed port. The two openings (vacuum and low-speed port) should not be confused. For further information on vacuum-advance mechanisms in ignition distributors, refer to *Automotive Electrical Equipment*, another of the books in the McGraw-Hill Automotive Mechanics Series.

§61. High-speed, part-load circuit When the throttle valve is opened sufficiently so the edge moves well past the low-speed port, the difference in vacuum between the upper part of the air horn and the low-speed port becomes very small. It is too small to cause any amount of air-fuel mixture to discharge from the low-speed port. However, under this condition, sufficient air is moving through the air horn to cause the high-speed circuit to function. The high-speed circuit includes the fuel nozzle (called the *main nozzle* or *high-speed nozzle*), the venturi, and the fuel passages from the float bowl to the nozzle (see Fig. 4-9). The partial vacuum in the venturi, produced by the air movement through it, causes the nozzle to discharge fuel into the air. This action is described in detail in §47. The air-fuel mixture produced is of the correct proportions to meet the intermediate throttle, part-load operating requirements. The main nozzle supplies the fuel during operation with the throttle valve partly to fully opened.

Actually, the low-speed circuit does not suddenly stop supplying air-fuel mixture, nor does the high-speed circuit suddenly begin to supply fuel when the throttle valve is slowly opened. The delivery of air-fuel mixture from the low-speed circuit gradually tapers off as the edge of the throttle valve swings past the low-speed port. During this interval the increasing flow of air through the air horn and the venturi sets the high-speed circuit into operation. Thus, the high-speed circuit gradually takes over as the low-speed circuit fades out. These two circuits are so carefully balanced that, as the throttle is gradually opened, a nearly constant air-fuel ratio is maintained during the shift from the low-speed to the high-speed circuit.

As engine speed increases, larger amounts of air pass through the air horn and venturi. This produces a greater vacuum in the venturi

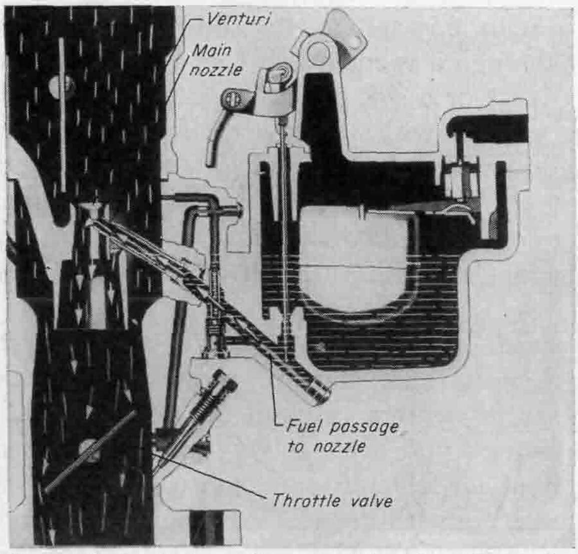


FIG. 4-9. High-speed circuit in carburetor. Throttle valve is fairly well open, and gasoline is being fed through high-speed nozzle. Lines indicate air; arrows indicate gasoline. (*Chevrolet Motor Division of General Motors Corporation*)

which, in turn, causes the main nozzle to discharge greater amounts of fuel. Thus a nearly constant air-fuel ratio is maintained by the high-speed circuit.

§62. Multiple venturi To assure more perfect mixing of the fuel and air, carburetors usually have multiple venturi, one inside another. An example of a triple-venturi carburetor is shown in Fig. 5-8. The upper, or primary, venturi produces the vacuum that causes the main nozzle to discharge fuel. The secondary venturi passes a blanket of air, which holds the spraying fuel away from the walls of the air horn, where it might otherwise condense. At the same time, turbulence between the central stream of air-fuel mixture and the outer blanket of air causes better mixing and finer atomization of the fuel spray. This same action is repeated in the main venturi.

§63. Other high-speed circuits Figures 4-10 and 4-11 illustrate other types of high-speed circuits in carburetors. Even though the various carburetors are somewhat different in appearance, design, and construction, they all function as explained in previous paragraphs; that is, the high-speed circuit takes over at some intermediate throttle opening as the low-speed circuit fades out. In the circuit

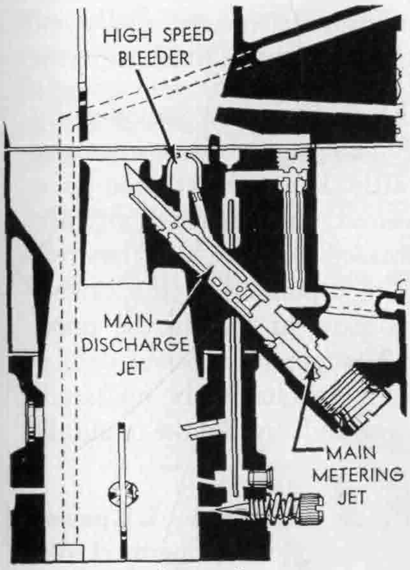


FIG. 4-10. High-speed circuit in carburetor. (*Studebaker-Packard Corporation*)

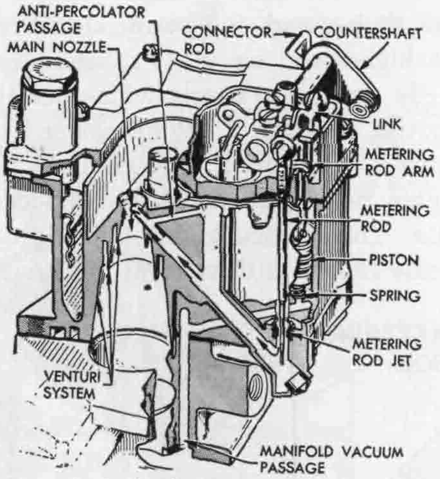


FIG. 4-11. Carburetor partly cut away so that high-speed circuit of one barrel can be seen. Fuel flow is shown by arrows. The carburetor is a dual, or two-barrel, unit. (*Buick Motor Division of General Motors Corporation*)

shown in Fig. 4-10 the high-speed bleeder allows air to be drawn into the main discharge jet where it mixes with the fuel. This causes a mixture of air and fuel to be discharged from the fuel nozzle; better atomization and vaporization of the fuel is thereby achieved. If any vapor bubbles form in the hot fuel as it moves up the main discharge jet, they follow the outside channel around the jet and collect in the high-speed bleeder dome. From there, the vapor bubbles are drawn down into the jet again, along with the bleeding air. This design assures more uniform delivery of fuel even during exceptionally hot operation.

The carburetor shown in partial cutaway view in Fig. 4-11 is a dual, or two-barrel, carburetor such as described in §60 and illustrated in Fig. 4-8. In operation, the high-speed circuit draws fuel from the float bowl, past the metering-rod jet, up the main nozzle passage, and out through the main nozzle. Fuel vapor bubbles that might form in the main nozzle passage rise through the low-speed jet passage and then exhaust through the antipercolator passage into the main nozzle. This assures uniform delivery of fuel even though extreme heat might be causing fuel vapor bubbles to form.

§64. High-speed, full-power circuit The air-fuel ratio provided by the high-speed circuit is satisfactory for all engine operation from partly opened to nearly wide-open throttle. However, at wide-open throttle, where full engine power is desired, an increase in mixture richness is required. To obtain this increased richness, and thus full engine power, an additional device is incorporated in the carburetor. This device admits an additional flow of fuel to the main nozzle so that it discharges more fuel. Two general types of device are in use—one mechanically operated, the other operated by intake-manifold vacuum.

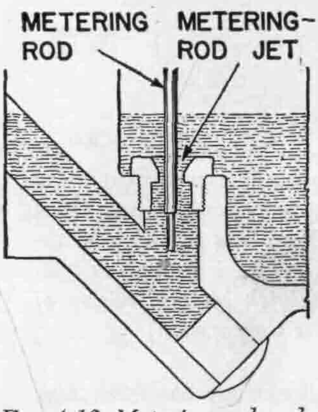


Fig. 4-12. Metering rod and metering-rod jet for securing added performance at full throttle.

§65. Mechanically operated full-power circuit The mechanically operated device makes use of a metering-rod jet and a metering rod with two or more steps of different diameters as shown in Fig. 4-12. The metering rod is connected to the throttle linkage, or connector rod, as shown in Fig. 5-8. When the throttle is opened, the throttle connector rod moves so that the metering rod is raised. At intermediate throttle, the larger diameter, or step, is in position in the metering-rod jet. This somewhat restricts the flow of fuel to the main nozzle. Sufficient fuel does flow, however, to provide the proper air-fuel ratio during intermediate throttle operation. But when the throttle is fully opened, the metering rod is raised enough to cause the smaller diameter, or step, to be lifted up into the metering-rod jet. The jet is therefore less restricted and a larger quantity of fuel can pass through it. The fuel nozzle therefore feeds more fuel and a richer mixture results.

In the carburetor shown in Fig. 4-11 the metering rod has three diameters, or steps. In this unit, the largest, or economy, step is in place in the metering-rod jet in the lower-speed ranges. However, when the throttle is partly opened for higher speed or acceleration, the metering rod is raised so that the middle step clears the jet. More fuel can therefore pass through the jet for satisfactory performance in the intermediate-speed range. When the throttle is fully opened, the metering rod is fully raised so that the smallest step is in the jet; this permits additional fuel delivery through the jet for full-power, high-speed performance.

§66. Vacuum-operated full-power circuit The full-power, full-throttle device may also be operated by intake-manifold vacuum, as shown in Fig. 4-13. The design illustrated makes use of a valve

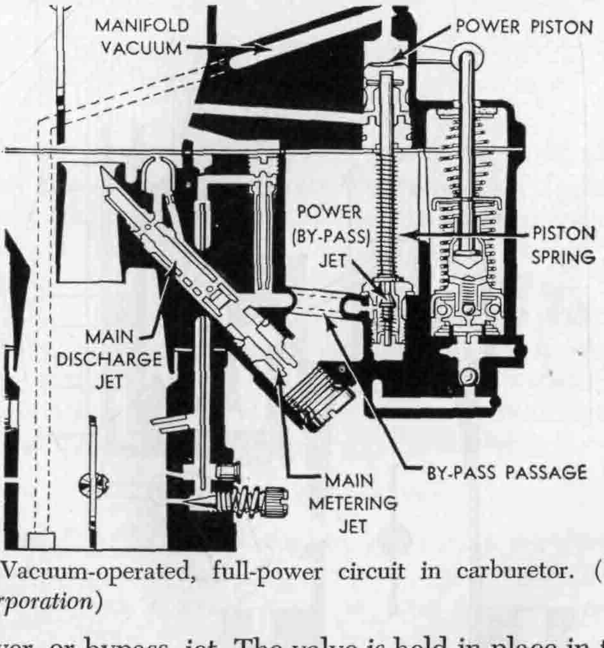


Fig. 4-13. Vacuum-operated, full-power circuit in carburetor. (*Studebaker-Packard Corporation*)

in the power, or bypass, jet. The valve is held in place in the bypass jet by a small spring during part-throttle operation. In this position no fuel can flow through the bypass jet; all fuel is fed to the main nozzle through the main metering jet. Above the valve is a vacuum piston (or power piston). The upper chamber above the power piston is connected through a vacuum channel to an opening just below the throttle valve. Under part-throttle operation, the vacuum in the intake manifold (or just below the throttle valve) is sufficient to hold the power piston up against the piston-spring tension. But when the throttle is opened wide, intake-manifold vacuum drops. The vacuum is then insufficient to hold the power piston. Now, spring pressure forces the piston down. The rod below the piston is also forced down, and the end of the rod moves down against the valve, causing it to open. Additional fuel can now be fed into the main nozzle through the bypass jet and bypass passage. This enriches the mixture for wide-open-throttle, full-power operation.

§67. Combination mechanically operated and vacuum-operated full-power circuit Some carburetors use a full-power circuit that has a combination device operating on both mechanical movement and intake-manifold vacuum (Figs. 4-11 and 4-14). On such applica-

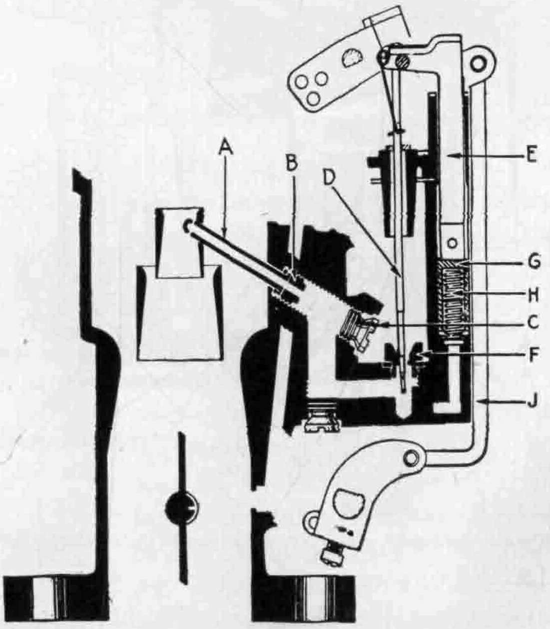


FIG. 4-14. Combination mechanically operated and vacuum-operated full-power circuit. Both vacuum-piston and throttle positions control position of metering rod. *A*, nozzle; *B*, retainer plug; *C*, plug; *D*, metering rod; *E*, linkage; *F*, metering-rod jet; *G*, vacuum piston; *H*, spring; *J*, linkage to throttle. (*American Motors Corporation*)

tions a metering rod is used, as described above. It is linked to the throttle so that wide-open throttle causes the smaller diameter of the metering rod to clear the metering-rod jet and feed additional fuel to the main nozzle. The metering rod is also linked to a vacuum piston which is assembled into a chamber in the carburetor. When the throttle is only partly opened and a vacuum is present in the intake manifold, the vacuum piston is held down in the chamber. However, when intake-manifold vacuum drops, regardless of throttle opening, the vacuum piston is pushed up by the piston spring. This movement is carried by a link to the metering rod, raising it. Now, more fuel is fed to the main nozzle, and a richer mixture results to provide full-power performance. When vacuum increases in the intake manifold, the vacuum piston is again pulled down so that the larger diameter of the metering rod enters the jet. This restricts the fuel flow, resulting in a leaner mixture. The metering rod is thus controlled by both intake-manifold vacuum and throttle position.

CHECK YOUR PROGRESS

Progress Quiz 1

This is the first progress quiz you have seen in this book, although you have already come across the chapter checkups. This chapter is longer than previous chapters, however, and thus it is a good idea for you to pause before you have finished the chapter to check your progress. This quiz and the chapter checkups have been put into the book to help you. They help you in two ways. First, they show you how well you are remembering the important points in the material you are reading. Secondly, they provide a review of the important points which helps fix them more firmly in your mind. If any of the questions seem hard to answer, reread the pages that will give you the answer.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. According to the graph of air-fuel ratios for different operating conditions, the ratio during engine idle is about *9:1* *12:1* *13:1* *15:1*
2. According to the graph of air-fuel ratios for different operating con-

ditions, the ratio during intermediate speed, part-throttle operation is about *9:1* *12:1* *13:1* *15:1*

3. Concentric-type float bowls contain a *dual-float assembly* *balance vent* *four-barrel setup*
4. Float bowls may be vented in two ways; when vented into the air horn, the carburetor is *a balanced carburetor* *an unbalanced carburetor* *a four-barrel carburetor* *a dual carburetor*
5. When the throttle is closed and the engine is idling, the air-fuel mixture flows *around the throttle valve* *past the idle adjustment screw* *past the main nozzle*
6. During low-speed operation, when the throttle is only slightly open, most of the fuel supplied to the engine is discharged through the *idle port* *low-speed port* *main nozzle* *venturi*
7. During high-speed operation, when the throttle is wide open, the fuel supplied to the engine is discharged through the *idle port* *low-speed port* *main nozzle*
8. The full-power circuit may be operated mechanically or by *metering rod* *intake-manifold vacuum* *linkage to throttle*

§68. Accelerator-pump circuit When the throttle is suddenly moved from a closed to an open position, a momentary out-of-balance condition results in the carburetor. For acceleration, the engine requires a relatively rich mixture; the sudden power demand means that the engine must have additional fuel richness. However, when the throttle is opened, the effect is to "dump" air into the intake manifold, thus suddenly reducing manifold vacuum. The sudden change in air flow, plus the need for a momentary richness, means that the main nozzle will not feed adequate fuel for acceleration. To carry the carburetor over this momentary lapse, which could cause a "flat spot" in engine performance (or logy acceleration), an acceleration-pump circuit is included in the carburetor.

Figure 4-15 shows a typical accelerator-pump circuit. It contains a pump assembled into the float bowl with a fuel passage up to a jet at one side of the air horn. The pump piston is linked to the throttle so that when the throttle is opened, the piston is pushed down. This downward movement forces fuel from the pump cylinder under the piston. The fuel moves through the fuel passage and out the pump jet into the air stream passing through the air-horn. This momentarily enriches the mixture and causes the engine to pick up speed quickly; quick, powerful acceleration results. A small check valve in the fuel

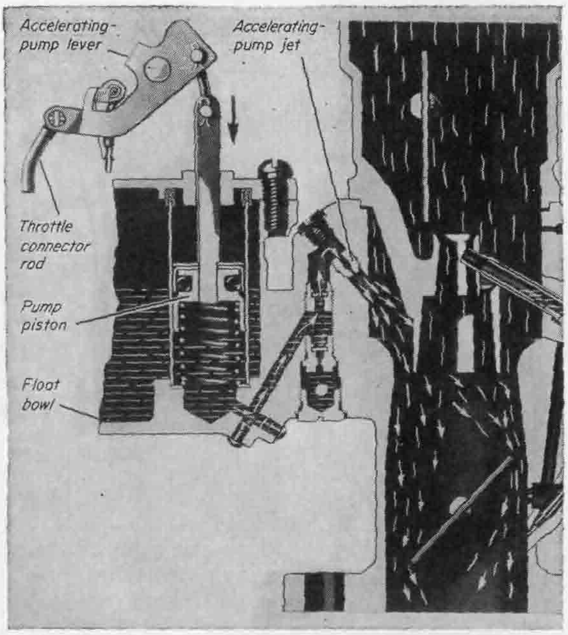


FIG. 4-15. Accelerator-pump system in carburetor. When the piston moves down, fuel is sprayed from the pump jet as shown by the arrows. (*Chevrolet Motor Division of General Motors Corporation*)

passage prevents fuel from being delivered to the air horn as a result of air velocity in the air horn. Fuel is delivered only when the throttle is opened and the accelerator-pump piston is forced downward.

§69. Other accelerator-pump circuits Figure 4-16 is a sectional view of a carburetor with an accelerator-pump circuit similar to the one described. Figure 4-17 shows a somewhat different accelerator-pump circuit used in a dual carburetor. This circuit contains two discharge nozzles, one for each carburetor air horn. Thus, in this carburetor the fuel from the accelerator-pump piston movement is split into two sprays, one for each air horn. All the various accelerator-pump circuits work in a similar manner. When the throttle is opened, the pump piston is forced downward and fuel is discharged into the air horn (or air horns). When the throttle is closed, the pump piston is pulled upward so that the pump chamber becomes refilled with fuel, ready for the next acceleration period. Most of the pistons are spring-loaded with a "duration" spring (see

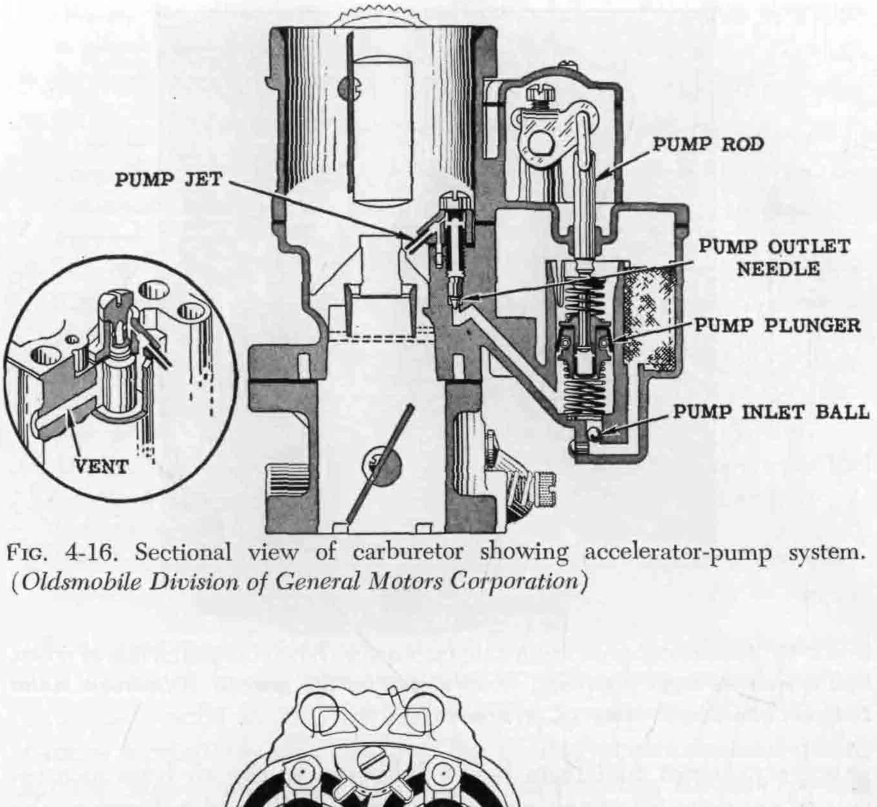


FIG. 4-16. Sectional view of carburetor showing accelerator-pump system. (*Oldsmobile Division of General Motors Corporation*)

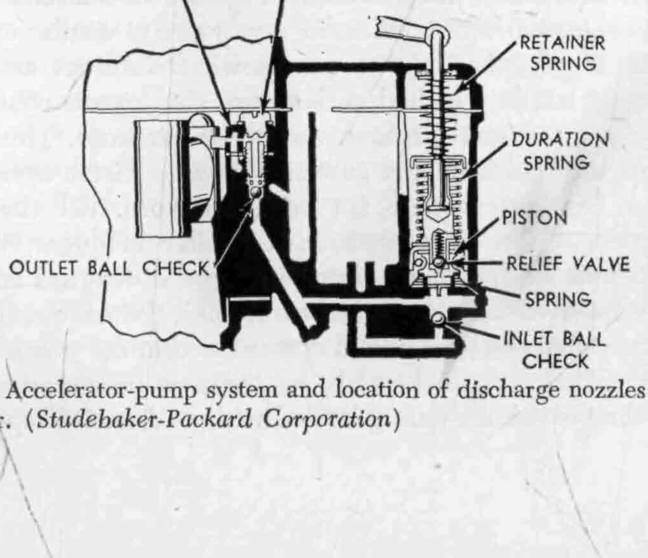


FIG. 4-17. Accelerator-pump system and location of discharge nozzles in a dual carburetor. (*Studebaker-Packard Corporation*)

Fig. 4-17). That is, the piston is not actuated directly by the throttle linkage, but through the spring. The throttle linkage actually compresses the spring, spring-loading the piston. Then the piston is moved by the spring to produce the fuel discharge. The purpose of the spring is to prevent excessive pressures in the pump and to give some duration (or length of time) to the fuel spray. This guards against a sudden momentary "squirt" of fuel and provides a more even enrichening effect that lasts for several seconds, or for as long as the spring continues to move the piston.

§70. Combination accelerator pump and full-power valve Some carburetors have the full-power valve so arranged that it is operated by the accelerator pump. With this arrangement, full-throttle position of the accelerator-pump piston forces the full-power valve off its seat so that additional fuel is delivered from the main nozzle. The valve operates as described in §§66 and 67. The only difference is that it is operated by the pump piston instead of by a vacuum piston or other throttle linkage.

§71. Choke When the engine is being cranked for starting, a very rich mixture must be delivered to the cylinders. Since normal cranking speeds may be below 100 rpm (revolutions per minute), air speeds through the carburetor are low. In addition, with a cold engine, the gasoline will not evaporate readily. Consequently, more than the normal amount of fuel must be delivered to the air stream passing through the air horn. The choke causes this fuel-delivery increase. The choke consists of a butterfly valve in the top of the air horn (Fig. 4-18). The valve is a round disk that can be tilted more or less in the air horn to choke off the air flow into the air horn more or less. It may be operated mechanically, thermostatically, by vacuum, or electricity. When the choke is closed (in position shown in Fig. 4-18) only a small amount of air can get past it. Thus, when the engine is being cranked with the choke closed, a fairly high vacuum is created in the air horn, causing the main fuel nozzle to discharge a heavy stream of fuel. The quantity delivered is sufficient to produce the very rich mixture needed for starting the engine.

The choke valve is not connected rigidly to the choke control, but is connected through a spring. The spring is strong enough to hold the choke closed during cranking. But when the engine starts, the sudden increase in vacuum (as engine speed increases to several hundred revolutions per minute) causes the choke valve to be partly opened (by atmospheric pressure above it). This admits more air and somewhat leans out the mixture for engine operation during the warm-up period. The choke valve may be unbalanced by being

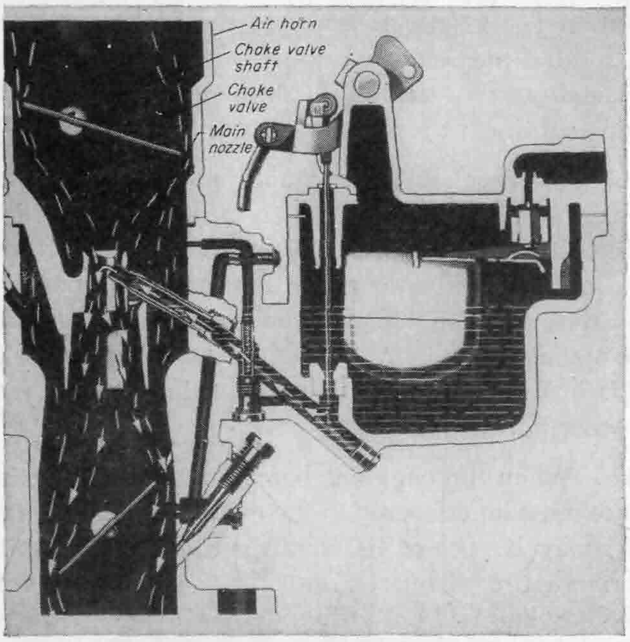


FIG. 4-18. Operation of choke when starting engine. (*Chevrolet Motor Division of General Motors Corporation*)

mounted off center on the choke-valve shaft (as shown in Fig. 4-18), or there may be a small spring-loaded section in the valve, which opens when the vacuum increases after the engine starts.

§72. Automatic chokes Mechanically controlled chokes are operated through a pull rod on the dash in the driving compartment. The pull rod is linked to the choke valve in the carburetor air horn, causing the choke valve to close when the rod is pulled out. A spring connection is incorporated at the choke valve so that the choke valve can spring partly open when the engine starts. The driver must remember to push the choke control back when the engine is warmed up. If he fails to do this, the engine will be supplied with an overrich mixture that will result in fouling of spark plugs and formation of carbon in the cylinders. To prevent such conditions, many carburetors now have automatic devices that close the choke valve when the engine is cold and gradually open it as the engine warms up. The automatic-choke devices are all similar, although they vary in detail. They operate on exhaust-manifold temperature and intake-manifold vacuum (Figs. 4-19 to 4-25).

In the typical automatic choke shown schematically in Fig. 4-19 a spiral bimetal-thermostat spring and a vacuum piston are linked together to the choke valve and control its position. The bimetal-thermostat spring is made up of two different metal strips welded

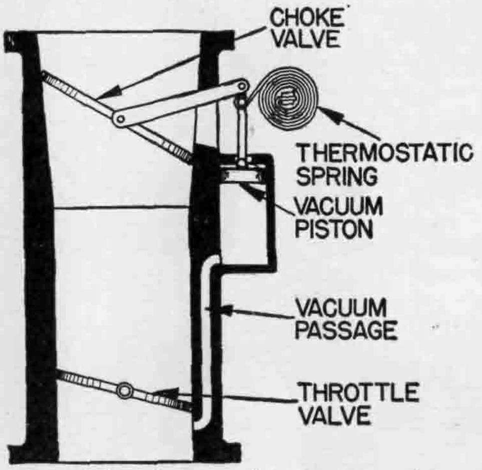


FIG. 4-19. Automatic choke shown schematically. Thermostatic spring and vacuum piston operate together to determine amount of choke-valve opening.

together and formed into a spiral. The two metals expand at different rates as the thermostat is heated, and this causes the spring to wind up. The spring unwinds when it cools. When the engine is cold, the spring has unwound enough to close the choke valve, and it spring-loads the choke valve in the closed position. When the engine is cranked, a rich mixture is delivered to the cylinders, and the engine starts. If the choke valve now remained completely closed, the mixture would be too rich even for initial running. On some applications a spring-loaded section of the choke valve is pulled downward by the vacuum in the air horn to permit additional air to pass so that the mixture is leaned out to some extent Other choke valves are unbalanced (choke-valve rod on one side) so that the vacuum in the air horn causes the valve partly to open against the thermostatic spring tension. The vacuum affects the vacuum piston in the choke also, causing it to move down against the thermostatic spring tension so that some additional opening of the choke valve is obtained. The carburetor thus supplies a mixture of the proper richness for operation during initial, cold-engine operation.

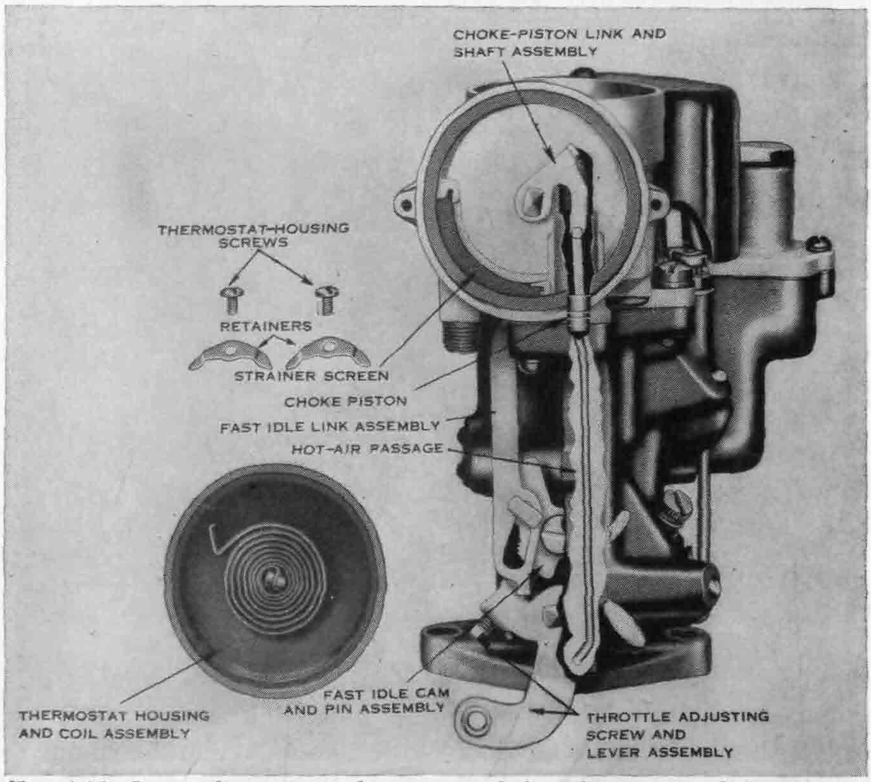


FIG. 4-20. Carter climate-control automatic choke. The vacuum-choke piston is connected through a vacuum channel to the intake manifold, while the thermostat housing receives heat through a hot-air passage from the exhaust manifold. (*Oldsmobile Division of General Motors Corporation*)

When the throttle is opened, the mixture must be enriched. The action of the accelerator pump (§68) does enrich the mixture momentarily, but additional richness is required, since the engine is cold. This added richness is secured by the action of the vacuum piston in the automatic choke. The opening of the throttle valve

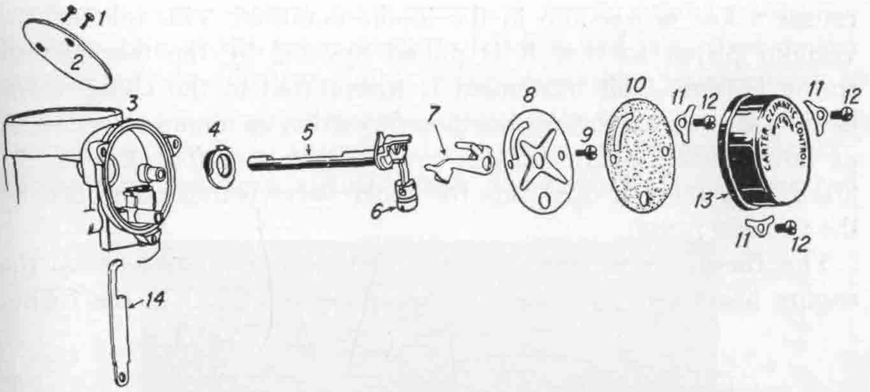


Fig. 4-21. Disassembled view of an automatic choke. Thermostatic spring is in the housing to right. (*Studebaker-Packard Corporation*)

1. Choke valve screws
2. Choke valve
3. Air horn and climatic-control housing
4. Fast-idle cam
5. Choke-valve shaft and lever
6. Choke piston
7. Choke trip lever
8. Baffle plate
9. Baffle-plate screw
10. Gasket
11. Retainer clip
12. Screw
13. Climatic-control housing with thermostat
14. Fast-idle link

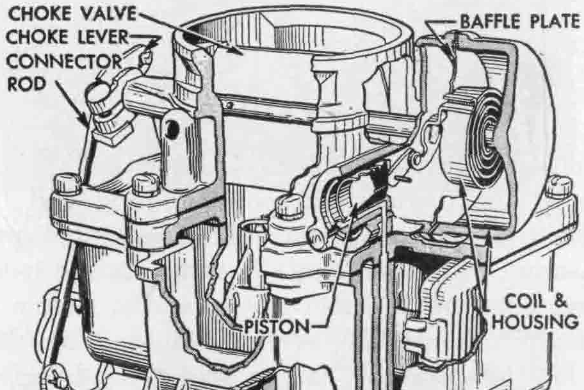


Fig. 4-22. Carburetor cut away so the automatic-choke construction can be seen. (*Buick Motor Division of General Motors Corporation*)

causes a loss of vacuum in the intake manifold. This releases the vacuum piston so that it is pulled upward by the thermostatic spring tension. This movement is transmitted to the choke valve, causing it to move toward the closed position an amount depending on how much vacuum remains in the intake manifold. During the first few seconds of operation the choke valve is thus controlled by the vacuum piston.

The thermostatic spring begins to take over, however, as the engine heats up. The thermostatic spring is placed in the carbu-

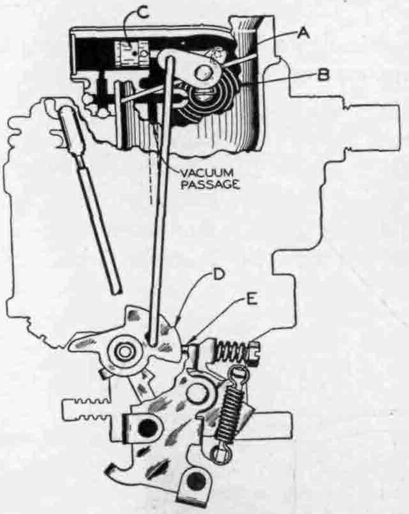


FIG. 4-23. Stromberg choke control. This design is much like the one in Fig. 4-20 except for the placement of the vacuum piston *C* and choke valve *A*, and the manner of linking the vacuum piston and the thermostatic spring *B* together. *D* is fast-idle cam and *E* is idle adjustment screw. (*Buick Motor Division of General Motors Corporation*)

retor in such a position that it is subjected to engine heat. A small tube connects the thermostatic-spring housing and the exhaust manifold. Heat passes through this tube, causing the spring to heat up. This heating of the thermostatic spring causes it to wind up. The winding takes place rather slowly as the engine approaches operating temperature, taking several minutes when the engine is started at low temperature. As the spring winds up, the spring tension holding the choke closed is gradually relieved, and the choke valve begins to open. When operating temperature is reached, the choke valve is completely open and, even though vacuum changes do take place in the intake manifold, the vacuum piston cannot cause the choke valve to close. During the interval of heating up, the vacuum piston can enrich the mixture when the throttle is opened, as has already been described. As the engine warms up, the operation of the vacuum piston has less and less effect on the richness of the mixture until, when operating temperature is reached, it has no further effect, the thermostatic spring having wound up enough to spring-load the choke in the open position. Before the choke can again operate, the engine must be stopped

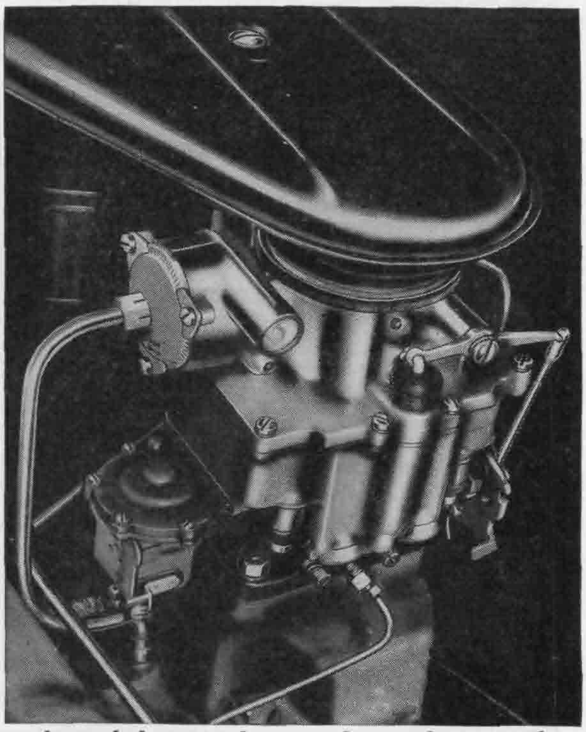


FIG. 4-24. Stromberg choke control mounted on carburetor. This is the exterior view of the choke control shown in previous illustration. (*Buick Motor Division of General Motors Corporation*)

and allowed to cool. As it cools, the thermostatic spring in the choke unwinds, causing the choke valve to close, so that the above sequence of operations will occur again. These chokes are often called *hot air* chokes since they operate when heated air from the exhaust manifold passes through them. Figures 4-20 to 4-25 illustrate various types of automatic-choke control.

A careful study of the various illustrations of automatic chokes will disclose that they are basically similar in construction and operation. The choke shown in Fig. 4-25 is somewhat different, however, and a further explanation of its action might be desirable. It operates electrically. When the starting motor is operated (to crank the engine), the electromagnet in the choke is energized. This causes the armature to be pulled upward so that the bimetal thermostat is pivoted upward. This action, in turn, causes the shaft in the choke to turn. Since the shaft is linked to the choke valve (see Fig. 9-3), turning of the shaft causes the choke valve to move toward the closed position. Then, after the engine starts and the

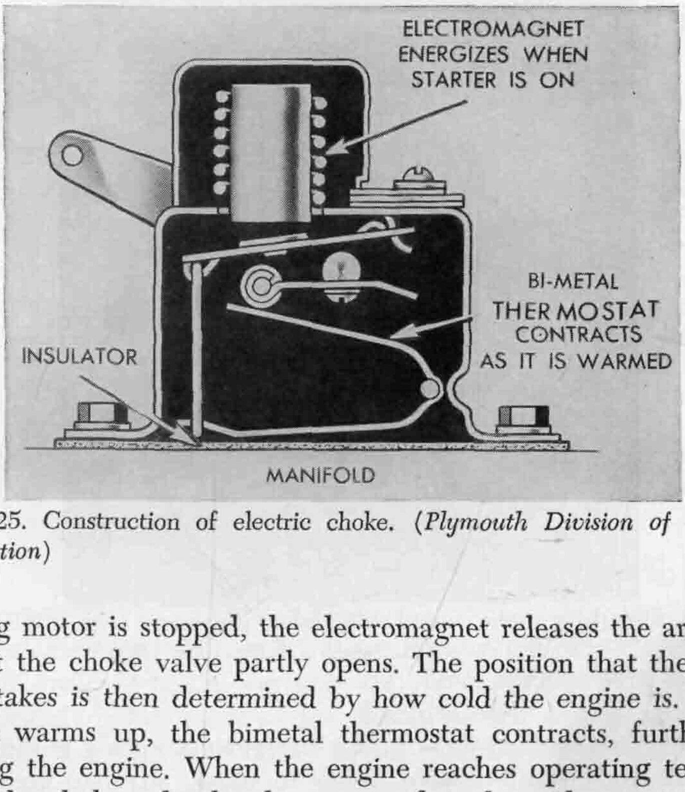


Fig. 4-25. Construction of electric choke. (*Plymouth Division of Chrysler Corporation*)

starting motor is stopped, the electromagnet releases the armature so that the choke valve partly opens. The position that the choke valve takes is then determined by how cold the engine is. As the engine warms up, the bimetal thermostat contracts, further de-choking the engine. When the engine reaches operating temperatures, the choke valve has been opened to the wide-open position.

§73. Manifold heat control As a further means of obtaining smooth engine operation during warm-up, a manifold heat control is used. This device causes considerable heat transfer from the exhaust manifold to the intake manifold during initial operation with a cold engine. The heat transfer preheats the air-fuel mixture and assures better fuel vaporization and thus better initial engine operation. To secure this heat transfer, the intake manifold is placed above the exhaust manifold, and there is an opening to the jacket that surrounds a part of the intake manifold (Figs. 4-26 and 4-27). Below this opening there is a thermostatically controlled butterfly valve, called the *manifold heat-control valve.*

The thermostat is a coiled spring made of two strips of different metals welded together. These two metals expand at different rates

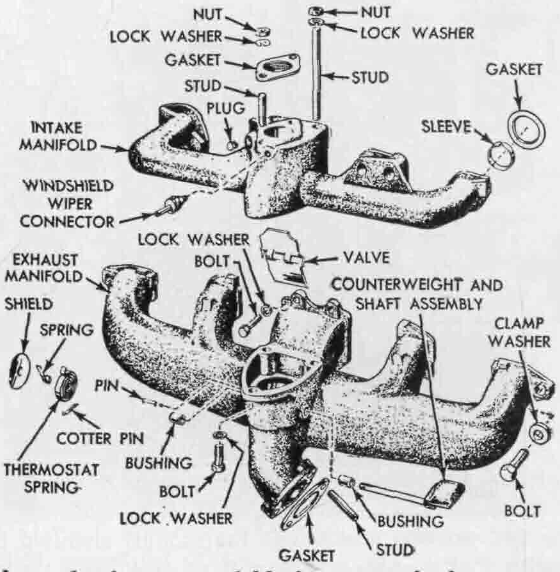


FIG. 4-26. Intake and exhaust manifolds for a six-cylinder engine. (*Ford Division of Ford Motor Company*)

as temperature increases; this causes the thermostat to wind up. When the temperature decreases, the thermostat unwinds. This latter condition causes the butterfly valve to assume the position shown in Fig. 4-26 when the engine is cold. Thus, when the engine first starts, the hot exhaust gases circulate through the jacket surrounding the intake manifold, quickly heating the intake manifold and assuring adequate vaporization of the fuel during the warm-up period of operation. An end view of this position is shown in the left-hand illustration in Fig. 4-27.

As soon as the engine begins to heat up, the thermostat, becoming hot, winds up, causing the heat-control valve to rotate into the position shown to the right in Fig. 4-27. This shields off the jacket surrounding the intake manifold, preventing any further flow of hot exhaust gases through it. Without such a "shutoff" arrangement, too much heat would be introduced into the intake manifold,

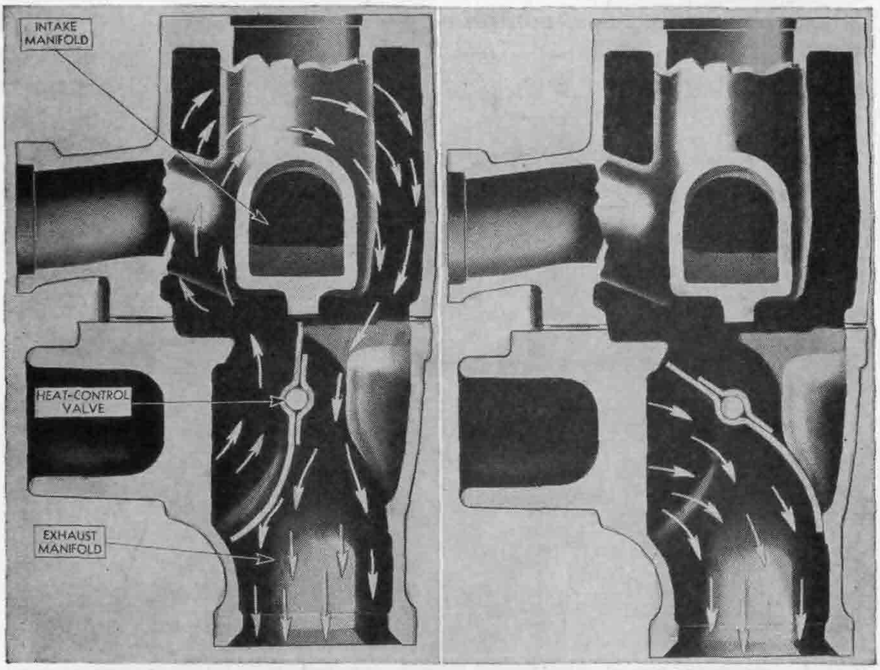


FIG. 4-27. The two extreme positions in the exhaust manifold of the manifold heat-control valve that controls the flow of exhaust gases through the intake-manifold jacket. (*Chevrolet Motor Division of General Motors Corporation*)

producing an excessive expansion of the air-fuel mixture, so that an insufficient quantity (by weight) would reach the engine cylinders.

§74. V-8 manifold heat control The heat-control arrangement described in the preceding section is for an in-line engine. A different arrangement is required for a V-8 engine since this type of engine normally has the intake manifold mounted between the two banks of cylinders, while there are two exhaust manifolds, one for each bank, mounted to the outsides of the banks. Thus in the V-8 engine there is a special passage in the intake manifold that carries exhaust gas from one exhaust manifold to the other (see Fig. 5-19). There is a thermostatically controlled valve in one exhaust manifold. When this valve is closed, that exhaust manifold cannot discharge through its own exhaust pipe. It must discharge through the special passage in the intake manifold and from there through the exhaust pipe for the other exhaust manifold. As the exhaust gas is shunted through this special passage in the intake manifold, it passes under the carburetor mounting pad (Fig. 4-28). Heat is thus introduced

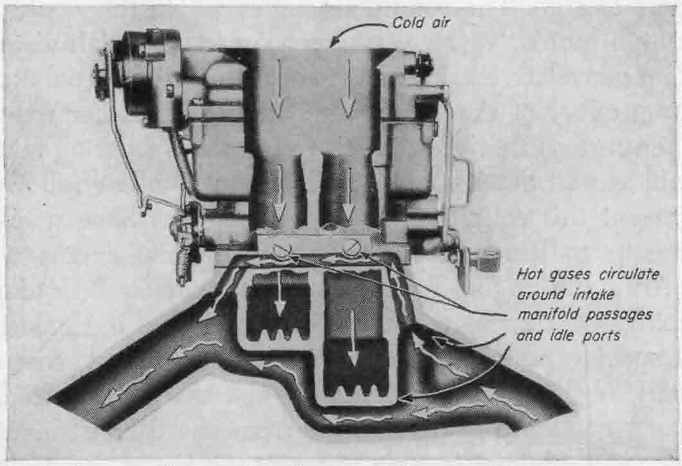


FIG. 4-28. Intake manifold and carburetor idle-ports heating passages. Hot exhaust gases heat these areas as soon as the engine starts. (*Cadillac Motor Car Division of General Motors Corporation*)

into the intake manifold. Then, when the engine warms up, the thermostatically controlled valve in the exhaust manifold opens to permit normal exhaust-gas discharge from both exhaust manifolds and pipes. The exhaust gases no longer pass through the intake-manifold passage.

§75. Anti-icing When fuel is sprayed into the air passing through the air horn, it evaporates, or turns to vapor. We have already noted that this is a change of state (§29) and that during the process, the fuel takes on heat. In other words, as the fuel vaporizes, it "robs" the surrounding air and metal parts of heat. This is the same effect that you get when you pour alcohol on your hand. The alcohol evaporates, "robbing" your hand of heat as it does so. Your hand feels cold. If you blow on your hand, thus causing the alcohol to evaporate faster, your hand will feel colder. The faster that evaporation takes heat away from your hand, the cooler your hand will feel.

In the carburetor the spraying and evaporating fuel takes considerable amounts of heat from the air. This cools the air. In fact, under certain conditions, the air and surrounding metal parts are cooled so much that any moisture in the air will condense on the metal parts and then freeze. The ice that forms can actually cause the engine to stall. The conditions under which this could happen include high humidity (air very damp, or having high water-vapor content) and relatively low air temperature. The cooling, or refrigerating, effect of the evaporating fuel then further reduces the air temperature so that water condensation and freezing take place. The ice blocks off the air passages and engine stalling follows.

To prevent this condition, many engines now have special anti-icing circuits to heat the carburetor during the engine warm-up period. After the engine has warmed up, there is little danger of ice forming. One arrangement for a V-8 engine is shown in Fig. 4-28; a special passage or circuit for hot exhaust gases is incorporated in the carburetor. During the warm-up period, when hot exhaust gases are being shunted from one exhaust manifold to the other (as explained in §74), some of the hot exhaust gas passes around the carburetor idle ports and near the throttle-valve shaft. This adds enough heat to guard against ice formation. Another carburetor has water passages in the carburetor. You can see one of the water passages into the throttle body of the carburetor shown in Fig. 4-3 (to lower right). The water used is the engine cooling water; a small amount of the cooling water bypasses through a special water manifold in the lower part (or throttle body) of the carburetor. This adds sufficient heat to the carburetor to prevent icing and consequent stalling of the engine during the warm-up period.

§76. Throttle cracker When the engine is cranked, the throttle must be partly opened, or *cracked,* so that enough air can get through the air horn and to the engine. To crack the throttle during engine cranking, a special linkage is installed between the cranking-motor-switch lever and the throttle linkage. When the cranking motor is operated, this special linkage causes the throttle to be opened a small amount. Figure 4-29 shows one type of linkage with a special tool installed to check the adjustment. Adjustment must be correct so that the throttle will be opened the proper amount during cranking.

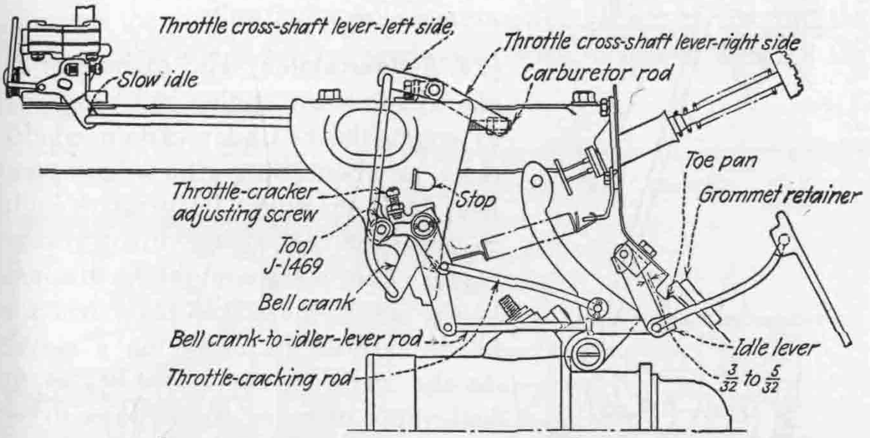


FIG. 4-29. Linkage connecting cranking-motor-switch lever and accelerator so that throttle is cracked during cranking. On solenoid-actuated cranking-motor-control systems, there is a linkage to the solenoid to perform the same function.

§77. Fast idle When the engine is cold, it is desirable to maintain some throttle opening so that the engine will idle faster than it would when warm. Otherwise, the slow idle, with the engine cold, might cause the engine to stall. The reason for this is that with the engine cold, a slow idle does not provide enough air for adequate fuel delivery and vaporization. But if the engine idles faster, the additional air passing through provides a much brisker air-fuel-mixture movement and better vaporization. To obtain fast idle with the engine cold, a fast-idle cam linked to the choke valve is used (Fig. 4-30). The automatic choke (not shown in illustration) controls the opening of the choke valve. During the warm-up period, the choke valve is fully or partly closed. In this position, the linkage to the fast-idle cam holds the cam so that the adjusting screw rests on the high section of the cam when the throttle is released. This means that the adjusting screw will not let the throttle close completely; the throttle is held partly open so that the engine idles fast. As the engine starts to warm up, the choke valve gradually opens (due to automatic-choke action). This causes the fast-idle cam to rotate. By the time the choke is fully opened, the fast-idle cam has rotated enough to have moved the high sections away from under the adjusting screw. Now, when the throttle is released, the adjusting screw can move into the low section of the fast-idle cam, and a normal slow idle results.

FIG. 4-30. Linkage between choke valve *G*, fast-idle cam, and throttle. When the fast-idle cam is in position shown, fast-idle adjusting screw does not allow throttle to close completely. *H*, screw; *K*, clearance. (*Buick Motor Division of General Motors Corporation*)

§78. Antipercolator The carburetor is placed above the engine and is subject to engine heat. Under certain conditions, as when idling after a hard run, heat build-up might be great enough to cause the high-speed circuit to percolate. This action might be likened to the action that takes place when a filled teakettle is placed on a stove. As the water in the kettle begins to boil, vapor pressure causes water to be forced out through the teakettle spout. However, the vapor pressure can be eliminated merely by lifting the teakettle lid. Similarly, by using a small vent in the high-speed circuit, vapor pressure can be relieved to prevent percolation in the circuit and thereby prevent boiling of the fuel out of the main nozzle. The antipercolating device used on some carburetors is connected into the throttle system so that a small valve opens as the throttle is released (Fig. 4-31). Another antipercolating device consists of a tube connected from the high-speed circuit to the upper part of the air horn (Fig. 4-11). This tube relieves vapor pressure sufficiently to prevent percolation.

§79. Air bleed In the high-speed circuits in many carburetors, devices are incorporated to permit air to enter, or *bleed* into, the high-speed or main nozzle. Some premixing of the fuel with air is thereby produced, so that the atomization is improved when the high-speed circuit is in operation (see Fig. 4-10). In addition, a better balance of the air-fuel-mixture ratio is maintained, since the speed and volume of air passing through the air horn (determined by throttle opening and engine speed) govern the amount of air that bleeds into the main nozzle. This combats the tendency for excessive gasoline to feed through the main nozzle when air speed through the air horn is high, since considerable air bleeds into the main nozzle under such a condition. When air speed through the

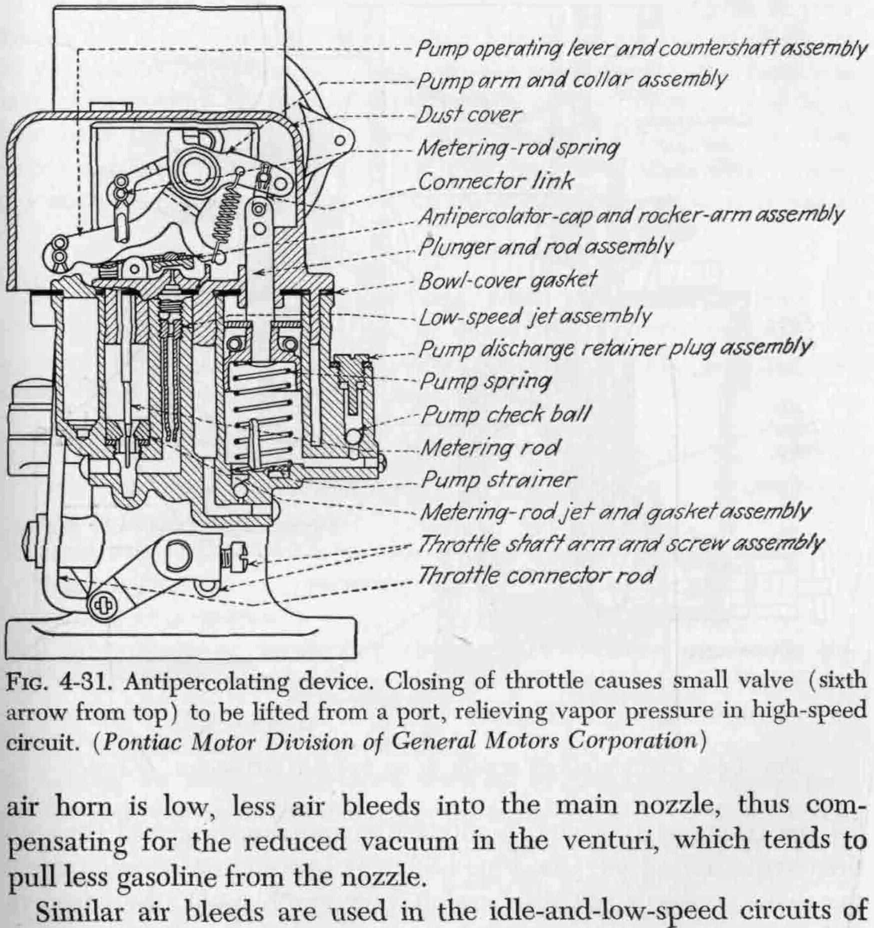


FIG. 4-31. Antipercolating device. Closing of throttle causes small valve (sixth arrow from top) to be lifted from a port, relieving vapor pressure in high-speed circuit. (*Pontiac Motor Division of General Motors Corporation*)

air horn is low, less air bleeds into the main nozzle, thus compensating for the reduced vacuum in the venturi, which tends to pull less gasoline from the nozzle.

Similar air bleeds are used in the idle-and-low-speed circuits of carburetors as explained in §60.

§80. Compensating system Several carburetor models use a compensating system (Fig. 4-32) which has the job of compensating for variations in fuel flow from the main nozzle. The main nozzle tends to discharge more fuel as engine speed (and air speed through air horn) increases. This tendency may cause an excessively rich mixture at higher speeds. But the compensating system, which includes a compensating nozzle, works in the reverse manner; it tends to lean out the mixture as engine speed increases. Thus, the main nozzle and the compensating nozzle work together to provide a mixture of uniform richness throughout the operating range. Fuel

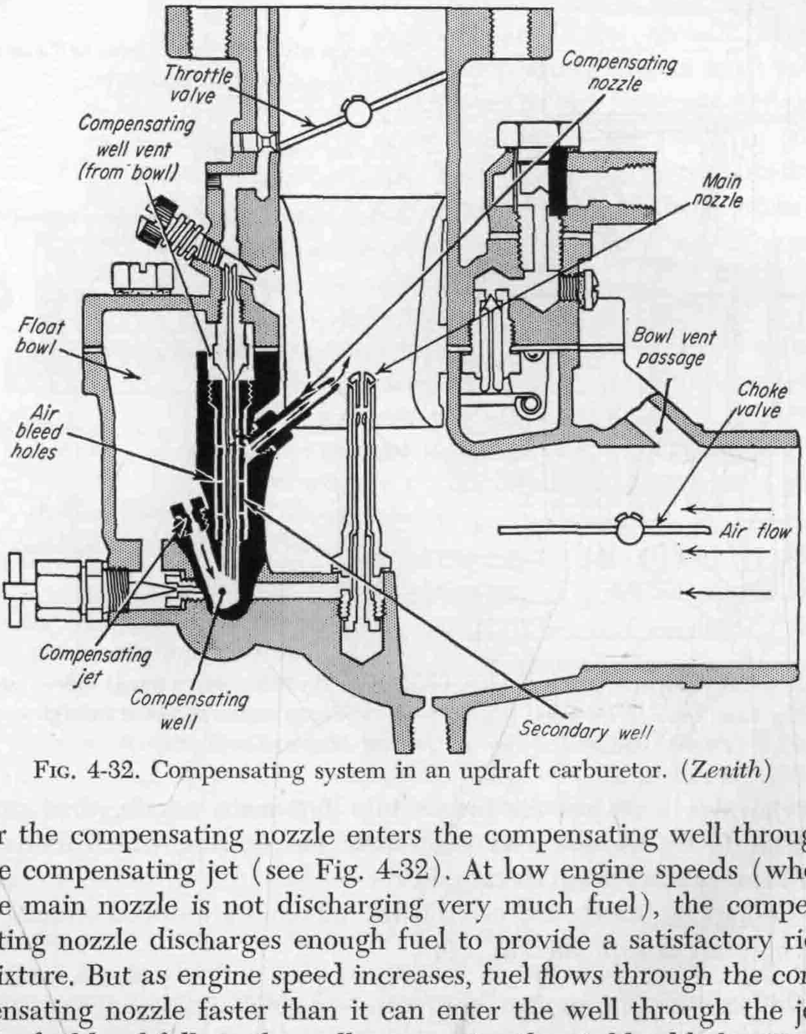


FIG. 4-32. Compensating system in an updraft carburetor. (*Zenith*)

for the compensating nozzle enters the compensating well through the compensating jet (see Fig. 4-32). At low engine speeds (when the main nozzle is not discharging very much fuel), the compensating nozzle discharges enough fuel to provide a satisfactory rich mixture. But as engine speed increases, fuel flows through the compensating nozzle faster than it can enter the well through the jet. The fuel level falls in the well, uncovering the air-bleed holes. Now, air begins to bleed into the compensating nozzle; the compensating nozzle discharges a leaned-out mixture. Meantime, however, the main nozzle discharges more fuel as engine speed increases. The combination provides a properly proportioned mixture for the operating condition.

CHECK YOUR PROGRESS

Progress Quiz 2

Once again you have the opportunity to check your progress in your studies of the automobile. The quiz that follows allows you to check up on yourself to determine how well you are remembering the facts you have been reading on the carburetor. Some of the questions may be a little hard for you to answer, but don't let that discourage you. Just reread the pages in the book that will give you the answers. This review, and answering the questions, will fix the important facts in your mind.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. In the accelerator-pump circuit fuel is forced into the air horn by movement of a *check valve* *metering rod* *discharge nozzle* *piston*
2. Dual carburetors (with two air horns) have accelerator-pump circuits with two *metering rods* *discharge nozzles* *pistons* *pumps*
3. The purpose of connecting the accelerator-pump piston to the throttle linkage through a spring is to give the fuel spray from the accelerator-pump circuit *higher pressure* *longer duration* *shorter duration* *faster starting*
4. Closing the choke valve when cranking or running the engine produces a vacuum in the carburetor air horn which *increases air flow* *leans out mixture* *increases fuel discharge from main nozzle*
5. The most commonly used automatic choke is operated by *vacuum and solenoid* *vacuum and thermostat* *thermostat and temperature*
6. As the engine warms up, winding up of the thermostat in the automatic choke causes the choke valve to *close* *release vacuum piston* *open*
7. When the engine is cold, opening of the throttle valve (which re-

duces intake-manifold vacuum) causes the vacuum piston to be released; this causes the choke valve to *move toward closed position* *move toward open position* *be held stationary*

8. When the engine is cold, the manifold heat control causes hot exhaust gases to circulate through a jacket around the *exhaust manifold* *intake manifold* *exhaust pipe* *tail pipe*
9. The fast-idle cam is rotated by linkage connected to the *throttle* *idle adjustment screw* *choke valve*
10. The purpose of the antipercolator is to relieve vapor pressure and thereby prevent boiling of the fuel from the *main nozzle* *percolator circuit* *drip circuit* *idle circuit*

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review *the chapter before taking the test.*

You have already taken a couple of progress quizzes as you went through the chapter. Now, you can take a general checkup test on the entire chapter. This helps you review again the essential points covered in the chapter. Repeated review of the important facts fixes them firmly in your mind. Then, when you get into the shop or are confronted with a problem on carburetors, you won't have to grope around in the dark. The facts will be there in your mind, ready to help you. If any of the questions that follow stump you, don't be alarmed. Just review the chapter again to get the facts "down pat." Write the answers in your notebook. This helps you remember and also assembles all the important facts on the subject in one place for your easy reference.

Correcting Parts Lists

The purpose of this exercise is to help you spot unrelated parts in a list. For example, in the list *idling circuits, float bowl, idle passage, idle adjustment screw, idler gear,* the only part that is not in the carburetor idling system is the *idler gear.* This name, therefore, does not belong.

In each of the lists below, you will find one item that does not belong. Write down each list in your notebook, but *do not write down* the item that does not belong.

1. Carburetor parts include air horn, throttle valve, main nozzle, exhaust pipe, venturi.
2. Carburetor circuits include idling-and-low-speed circuits; float circuit; high-speed, part-load circuit; ignition circuit; high-speed, full-power circuit.
3. Float-circuit parts include float bowl, float, needle valve, vent, float rings.

4. Idling circuit includes float bowl, idling-and-low-speed passage, idle adjustment screw, idle gears.
5. Full-power circuit may include such items as main nozzle, recharge lever, vacuum-operated piston, metering rod, metering-rod jet.
6. Accelerator-pump circuit includes pump piston, check valve, discharge nozzle, linkage to throttle, main nozzle.
7. Automatic choke may include such items as choke valve, thermostat, solenoid diaphragm, vacuum piston.
8. Special features of carburetors include such items as air bleed, oil bleed, antipercolator, throttle cracker, fast-idle cam.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The circuit in the carburetor that is responsible for maintaining a constant-level reservoir of fuel is called the *fuel circuit* *level reservoir* *float circuit* *carburetor circuit*
2. When the engine is idling, all the fuel burned by the engine must pass the *idle adjustment screw* *idle-speed setscrew* *main nozzle*
3. Float bowls may be vented in either of two ways, *to air horn or atmosphere* *to main nozzle or idle circuit* *to float or air cleaner* *to atmosphere or float*
4. When the float bowl is vented to the atmosphere, the carburetor is *a balanced carburetor* *an unbalanced carburetor* *a dual carburetor*
5. With the throttle only slightly opened, intake-manifold vacuum causes *venturi action* *fuel discharge from main nozzle* *fuel discharge from low-speed port*
6. With the throttle wide open, venturi action, producing a vacuum, causes *fuel discharge from main nozzle* *fuel discharge from low-speed port* *fuel discharge from accelerator jet*
7. As the throttle valve is moved from the closed to the opened position, a spray of fuel is discharged into the air horn from the *low-speed port* *accelerating-pump jet* *idle port* *main nozzle*
8. As the carburetor full-power circuit begins to function, additional fuel is delivered to the main nozzle due to the movement of a *thermostat or butterfly valve* *metering rod or vacuum piston* *thermostat and vacuum piston*

9. In the automatic choke the position of the choke valve is controlled by *metering rod or vacuum piston* *thermostat and vacuum piston* *fast-idle cam or throttle linkage*
10. The fast-idle cam, which is linked to the automatic-choke valve, causes the engine to idle fast when the engine is *cold* *warm* *overheated*

Purpose and Operation of Components

In the following, you are asked to answer questions about certain components in the fuel system, discussed in the chapter you have just finished. If you have any difficulty in writing down your explanations, turn back into the chapter and reread the pages that cover the item you are writing about. Then write down your explanation. Don't copy; try to tell it in your own words. This is a good way to fix the information in your mind. Write in your notebook.

1. What are the names of the circuits of the carburetor?
2. How do the float and needle valve work to maintain a constant fuel level in the float bowl?
3. What two ways are float bowls vented, and what are the names given to carburetors with these two venting methods?
4. How does the metering rod work when the full-power circuit goes into operation?
5. How does the accelerator pump operate?
6. How does the automatic choke operate?
7. What is the purpose of the manifold heat control, and how does it operate?
8. What is the purpose of the anti-icing circuits discussed in the book?
9. What is the purpose of the throttle cracker?
10. What is the purpose of the antipercolator?

SUGGESTIONS FOR FURTHER STUDY

Continue your studies of actual fuel-system components in your school shop or automotive service shop. As you handle carburetors and carburetor parts, you will understand more clearly how these units operate and what the various parts do in the complete working assembly. Manufacturers of carburetors and automobile engines prepare service manuals for the use of engine servicemen. If you can borrow these from your school automotive shop library or from a friendly service shop, study them carefully, for they have much valuable information in them. Write down in your notebook important points about carburetors that you might learn in the shop or from the manuals.

5: Automotive carburetors

THE PURPOSE of this chapter is to describe different accessory devices used on modern carburetors and to discuss in detail various carburetors used on modern automotive vehicles.

§81. **Accessory devices on carburetors** In previous chapters we discussed the various circuits and devices on automotive carburetors that contribute to good engine performance under various operating conditions. These circuits and devices include the idling-and-low-speed circuits, the high-speed circuits, accelerator pump, choke, and manifold heat control. In addition to these, various carburetors have special accessory devices that do certain specific jobs on the vehicle, such as:

1. Vacuum circuits to control the ignition-distributor spark advance.
2. Electric switches to operate the starting-motor control circuit.
3. Throttle-return checks and magnetically controlled dashpots to retard throttle closing under certain conditions.
4. Electric kick-down switches that are tied into the operation of certain types of automatic transmissions.
5. Governors to control or limit top engine speed.

§82. **Ignition-distributor controls** The vacuum circuits to ignition distributors have already been mentioned briefly in the note at the end of §60. The purpose of such circuits is to carry intake-manifold vacuum into the ignition distributor when the throttle valve is opened just past the idle position. During idle and low-speed operation there is vacuum in the intake manifold, and this means that less air-fuel mixture will enter the cylinders. The mixture will be less highly compressed and will burn more slowly on the combustion stroke. In order to obtain more power from the mixture under these conditions, the ignition spark must occur earlier in the cycle.

This is accomplished by carrying intake-manifold vacuum to a vacuum-control device on the distributor (Fig. 5-1). When the throttle valve swings past the vacuum opening in the carburetor air horn (Fig. 5-1), intake-manifold vacuum acts through the vacuum passage and causes a spring-loaded diaphragm to move inward. In the unit shown, this causes the distributor to rotate a few degrees in its mounting. As a result, the distributor contact points open earlier in the cycle to produce a spark advance. The mixture therefore gets an earlier start in its combustion and has more time to give up its power to the downward-moving piston. On other distributors

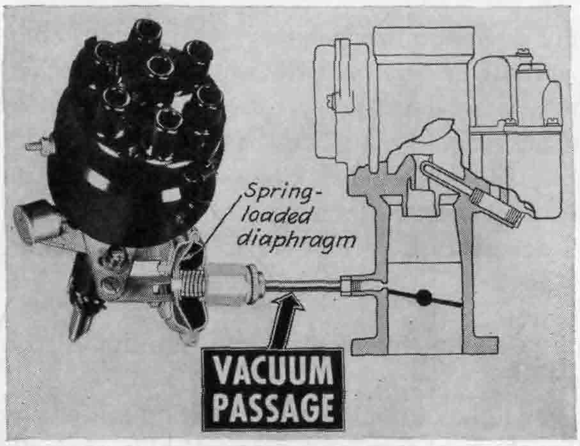


FIG. 5-1. Vacuum-line connection between distributor vacuum-advance mechanism and carburetor. (*Delco-Remy Division of General Motors Corporation*)

the breaker plate in the distributor is rotated instead of the complete distributor.

Another variation of this type of control is illustrated in Fig. 1-26. The carburetor with which it is used is shown in sectional view in Fig. 5-2. There are two vacuum-line connections into the carburetor air horn. The lower connection at *B* operates as described in the previous paragraph and supplies an advance based on intake-manifold vacuum. The upper connection at *A* supplies a spark advance based on engine speed. The higher the speed, the faster the air moves through the venturi. This means an increased vacuum and a greater spark advance. This advance, based on speed, gives the air-fuel mixture in the cylinders enough time to ignite, burn, and give up its power to the pistons. Other distributors use a centrifugal device to obtain spark advance based on speed (§§19 and 20).

The subject of distributor-advance mechanisms is covered in detail in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Electrical Equipment*).

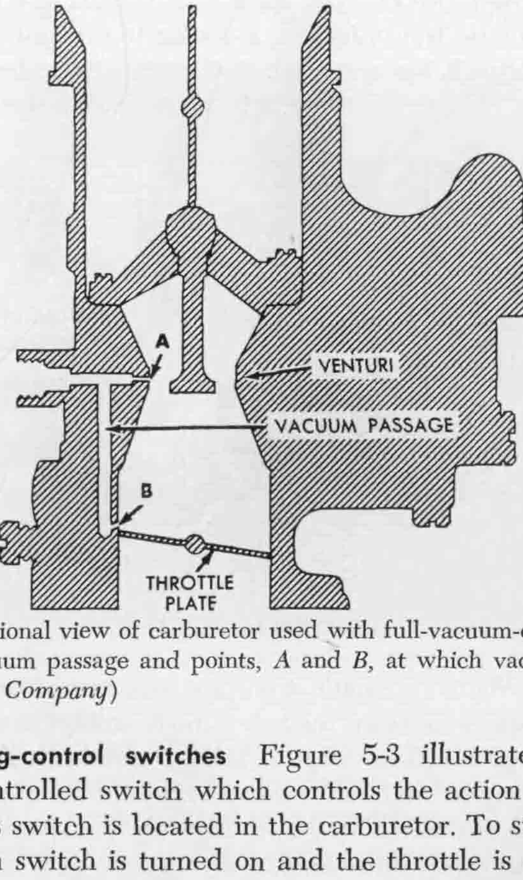


FIG. 5-2. Sectional view of carburetor used with full-vacuum-control distributor showing vacuum passage and points, *A* and *B*, at which vacuum is obtained. (*Ford Motor Company*)

§83. Starting-control switches Figure 5-3 illustrates a ball-type, vacuum-controlled switch which controls the action of the starting motor. This switch is located in the carburetor. To start the engine, the ignition switch is turned on and the throttle is opened. As the throttle is opened, the throttle shaft turns, forcing the ball in against the switch plunger. The plunger is thereby forced to move in against the return spring so that the contact spring connects between the two switch terminals. Electric current now flows through the switch. This current operates electromagnetic controls on the starting motor. These controls, in turn, connect the starting motor to the battery so that starting takes place. After the engine starts and the throttle is released, the intake-manifold vacuum pulls the ball upward out of the way. Now, the throttle can be operated and the throttle shaft turned without operating the switch. Further details of starting-motor controls are found in *Automotive Electrical Equipment*, another book in the McGraw-Hill Automotive Mechanics Series.

§84. Throttle-return checks On some carburetors used on certain cars with automatic transmissions, a device to prevent sudden closing of the throttle is incorporated. Such a device is desirable since sudden closing of the throttle might cause momentary hesitation

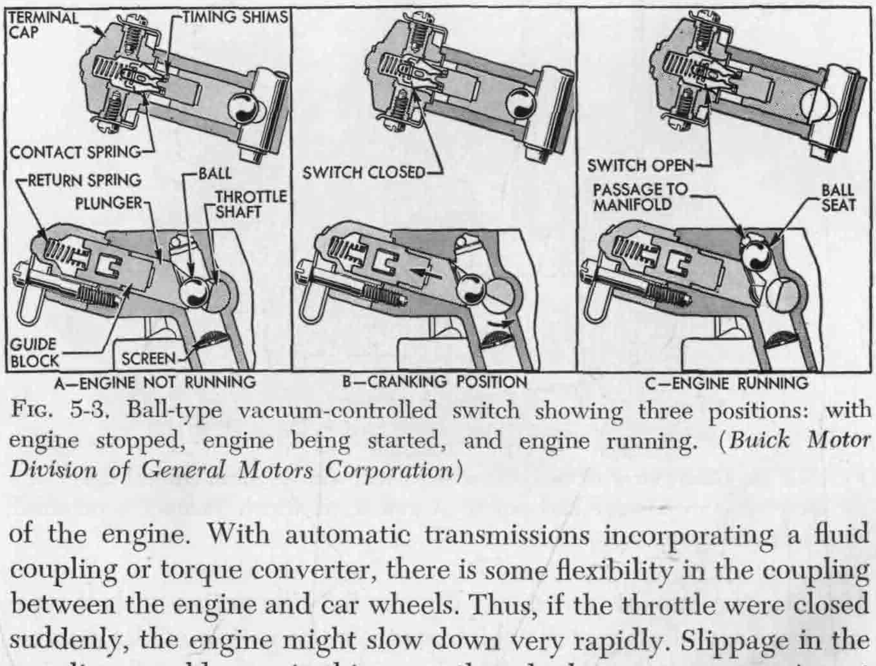


FIG. 5-3. Ball-type vacuum-controlled switch showing three positions: with engine stopped, engine being started, and engine running. (*Buick Motor Division of General Motors Corporation*)

of the engine. With automatic transmissions incorporating a fluid coupling or torque converter, there is some flexibility in the coupling between the engine and car wheels. Thus, if the throttle were closed suddenly, the engine might slow down very rapidly. Slippage in the coupling would permit this even though the car were moving at good speed. The rapid slowdown of the engine, as it was suddenly throttled down, could so unbalance carburetor action as to cause a momentary hesitation in the engine.

To prevent this, many carburetors on cars equipped with automatic transmissions use a throttle-return check. Figure 5-4 illustrates one type of check. It contains a spring-loaded diaphragm which traps air behind it when the throttle is opened, and the shaft and adjusting screw on the check move outward. Then, when the throttle is released, the contact arm on the throttle lever moves against the check adjusting screw. Since the air trapped back of the spring-loaded diaphragm can escape only slowly, the throttle is checked at this point and moves on to the closed position with relative slowness.

Another type of throttle-return check is shown in Fig. 5-5. In this unit, called a *dashpot*, the mechanism is controlled by a small electromagnet which causes the dashpot to check the throttle return

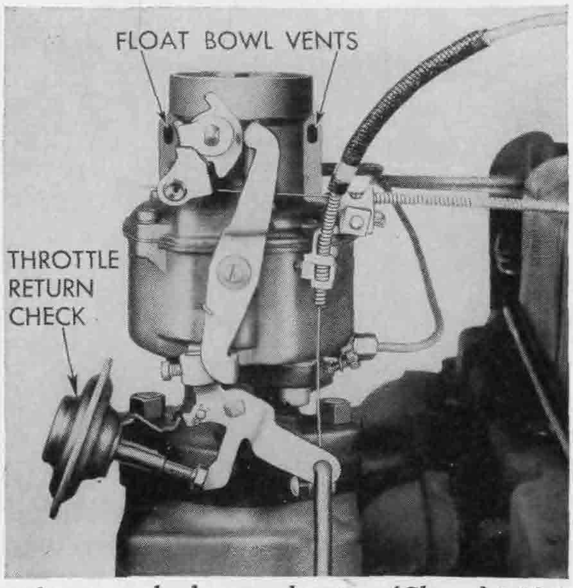


FIG. 5-4. Throttle-return check on carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

at some times but not at others. A speed-governor device on the transmission determines when the dashpot should work. Above a certain speed (governed speed of transmission), the electromagnet is not operating and the check ball is not seated. Thus, the air passage back of the dashpot diaphragm is open and the dashpot offers no restriction of closing of the throttle. However, at lower speeds, the electromagnet is energized and the check ball seated. This restricts air flow and retards dashpot diaphragm movement and thus throttle closing.

Also used on the carburetor illustrated in Fig. 5-5 is a special kick-down switch which operates when the throttle is depressed to wide-open position with car speeds below 40 to 45 mph (miles per hour). Above this speed the intake-manifold vacuum holds the kick-down switch piston up so the switch cannot work. The purpose of this switch is to provide a means for the driver to shift down to a lower transmission gear automatically by simply pushing the throttle down.

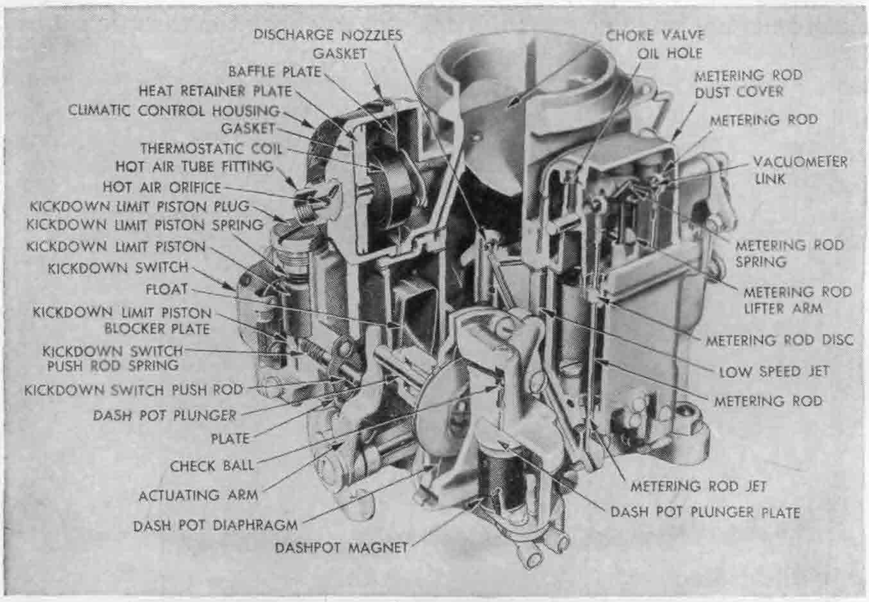


FIG. 5-5. Carburetor cut away to show dashpot, kick-down switch, and choke construction. (*Chrysler Sales Division of Chrysler Corporation*)

Operation of various automatic transmissions and transmission controls is covered in detail in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Transmissions and Power Trains*).

§85. Governor Engine-speed governors prevent overspeeding of the engine. They are used primarily on trucks and busses and have two purposes, to prevent excessive vehicle speed and to prevent excessive engine wear. A truck is designed to have satisfactory high-speed performance when loaded. Thus, when unloaded, it could operate at excessively high and dangerous speeds. Not only does this increase the chances of an accident, but also it overspeeds the engine, thus increasing engine wear. But a truck engine can also be overspeeded at low vehicle speeds. For example, suppose the safe maximum engine speed is 3,600 rpm (revolutions per minute). Suppose this gives the truck a level-road speed, when loaded and in high gear, of 60 mph. But suppose the driver shifts to a low gear to pull up a hill. Without a governor, he could very well overspeed the engine. For instance, suppose the gear ratio is such as to give 10 mph at 3,600 engine rpm. But the driver holds the accelerator down so that the truck speed increases to 15 mph. This means the engine is turning at 4,800 rpm. Such high engine speed is very damaging to the engine and greatly shortens the life of bearings and other engine parts.

To prevent such damage and reduce accident hazards from high vehicle speeds, governors are used. They are of two general types, the centrifugal type, and the velocity and vacuum types.

1. *Centrifugal type.* The centrifugal governor is driven mechanically from the engine. It has centrifugal weights that move out against gravity or spring tension as engine speed increases. This movement is carried by mechanical linkage to the carburetor and throttles down the air-fuel flow to the engine as maximum-rated engine speed is reached. The throttling action may take place directly on the throttle valve in the carburetor (by imposing a closing force on it) or on a separate butterfly valve placed below the throttle valve.

2. *Velocity and vacuum types.* Velocity and vacuum types of governors mount between the carburetor and the intake manifold (Figs. 5-6 and 5-7). The velocity type of governor has a throttle plate that is mounted off center. It is held open by a spring. As engine speed increases, the air-fuel mixture moves faster through the carburetor air horn and through the governor. The increased velocity of the air-fuel mixture tends to close the governor throttle; it strikes the unbalanced part of the throttle and pushes it toward the closed position. Opposing this force is the spring tension. As governed speed is attained, the two opposing forces position the throttle in a partly closed position. This position admits just enough air-fuel mixture to maintain governed speed. The vacuum type of governor works in almost the same way except that the closing force comes from intake-manifold vacuum. Intake-manifold vacuum increases with increased speed. This increasing vacuum acts on a vacuum piston that is linked to the governor throttle. The vacuum

tries to close the throttle; a spring tries to hold it open. A balance of forces is struck when the governed speed is attained. The throttle is held open just enough to admit sufficient air-fuel mixture for the engine to maintain governed speed.

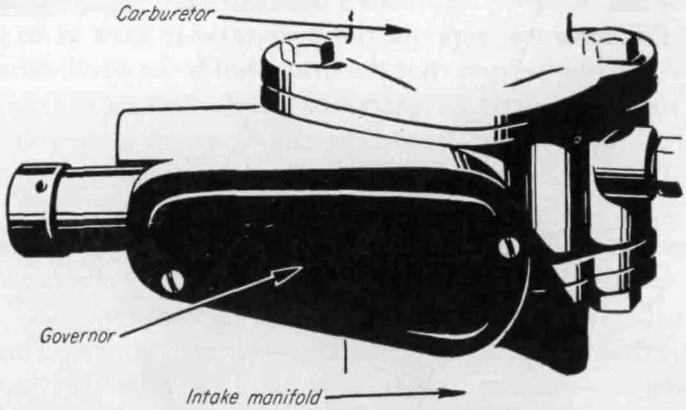


FIG. 5-6. Velocity, or vacuum, type of governor mounted between intake manifold and carburetor.

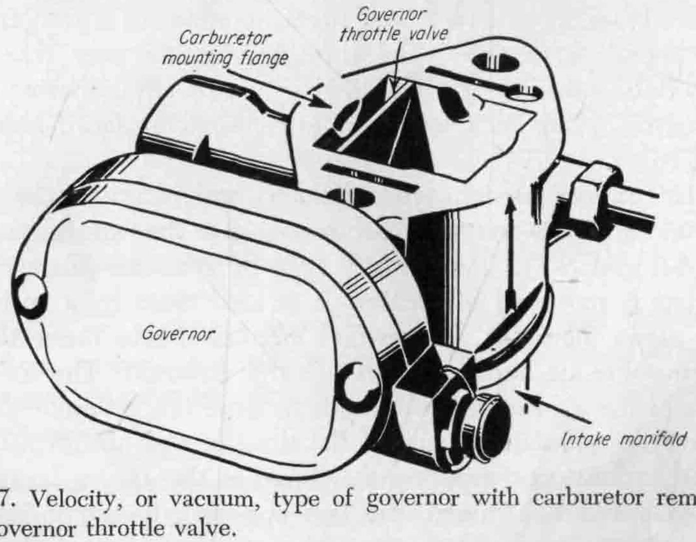


FIG. 5-7. Velocity, or vacuum, type of governor with carburetor removed to show governor throttle valve.

3. *Combination centrifugal-vacuum governor.* One type of governor operates on both principles (centrifugal and vacuum). The centrifugal unit is mounted on the ignition distributor; the centrifugal weights operate an air-bleed valve. The vacuum unit is mounted on the carburetor; it contains a diaphragm which is linked

to the throttle-valve shaft. In operation, increased engine speed causes the centrifugal unit to shut the air-bleed valve. This closes a passage to the vacuum unit. Now, intake-manifold vacuum can actuate the diaphragm in the vacuum unit; this causes the throttle valve to be moved toward the closed position and thus prevents any further increase of engine speed. The engine is held at governed speed.

§86. Carburetor assembly All the features discussed in previous sections may not be incorporated in a single carburetor. But dif-

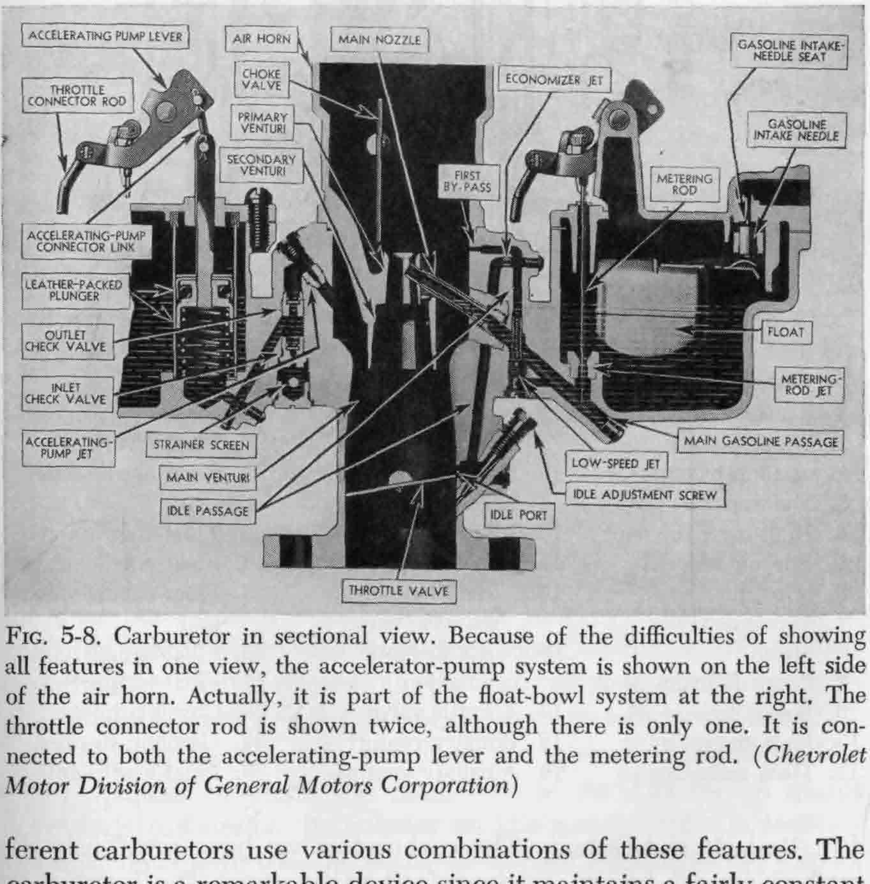


FIG. 5-8. Carburetor in sectional view. Because of the difficulties of showing all features in one view, the accelerator-pump system is shown on the left side of the air horn. Actually, it is part of the float-bowl system at the right. The throttle connector rod is shown twice, although there is only one. It is connected to both the accelerating-pump lever and the metering rod. (*Chevrolet Motor Division of General Motors Corporation*)

ferent carburetors use various combinations of these features. The carburetor is a remarkable device since it maintains a fairly constant air-fuel-mixture ratio throughout the normal intermediate driving range and also enriches the mixture when a rich mixture is required for starting, warm-up, and high-speed operation. Figures 5-8 and

5-9 are sectional views of carburetors having many of the features described on previous pages. Other carburetor models are discussed in following sections.

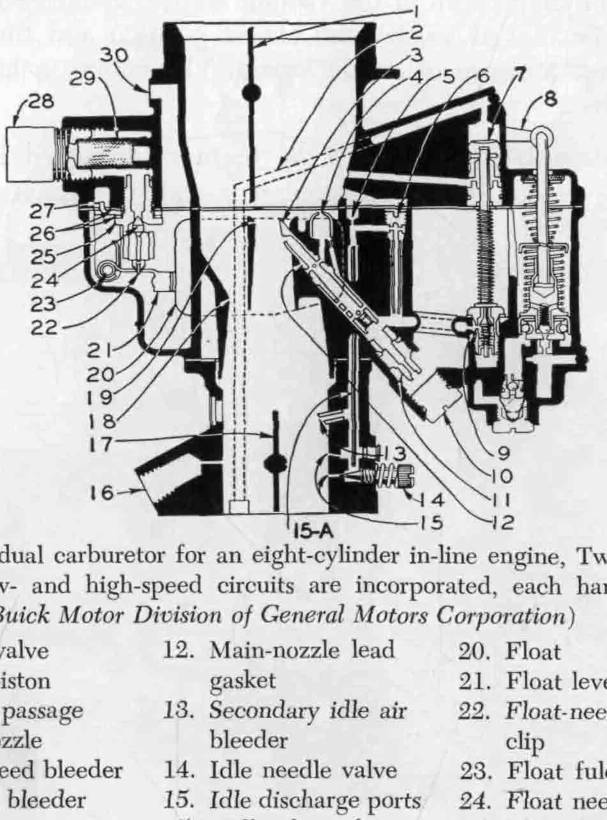


FIG. 5-9. A dual carburetor for an eight-cylinder in-line engine, Two air horns and two low- and high-speed circuits are incorporated, each handling four cylinders. (*Buick Motor Division of General Motors Corporation*)

1. Choke valve
2. Power-piston vacuum passage
3. Main nozzle
4. High-speed bleeder
5. Idle air bleeder
6. Idle tube
7. Vacuum power piston
8. Pump fulcrum arm
9. Power bypass jet
10. Main-nozzle plug
11. Main metering jet
12. Main-nozzle lead gasket
13. Secondary idle air bleeder
14. Idle needle valve
15. Idle discharge ports
15A. Idle channel-reducer wire
16. Vacuum-spark connection
17. Throttle valve
18. Primary venturi
19. Auxiliary venturi
20. Float
21. Float lever
22. Float-needle-valve clip
23. Float fulcrum pin
24. Float needle valve
25. Float-needle-valve seat
26. Float-hanger gaskets
27. Float hanger
28. Gasoline inlet
29. Gasoline strainer
30. Float-bowl vent

§87. Updraft carburetors The carburetors we have previously described are all known as *downdraft* carburetors. The ingoing air moves *downward* through the air horn. Some carburetors are of the updraft type; in these units the air moves *upward* through the air horn. Downdraft carburetors are mounted on top of the intake manifold. But updraft carburetors are mounted below the intake manifold; the air-fuel mixture flows upward from the carburetor into the intake manifold. Updraft carburetors are used on applications where there may not be enough headroom above the engine to accommodate a downdraft carburetor. Essentially, both types of carburetor operate in the same manner. Typical updraft carburetors are described in the following paragraphs.

1. *Float circuit.* Figure 5-10 shows, in sectional view, the float circuit of an updraft carburetor. The float circuit includes a needle valve actuated by a lip on the float arm, as in other carburetors. As

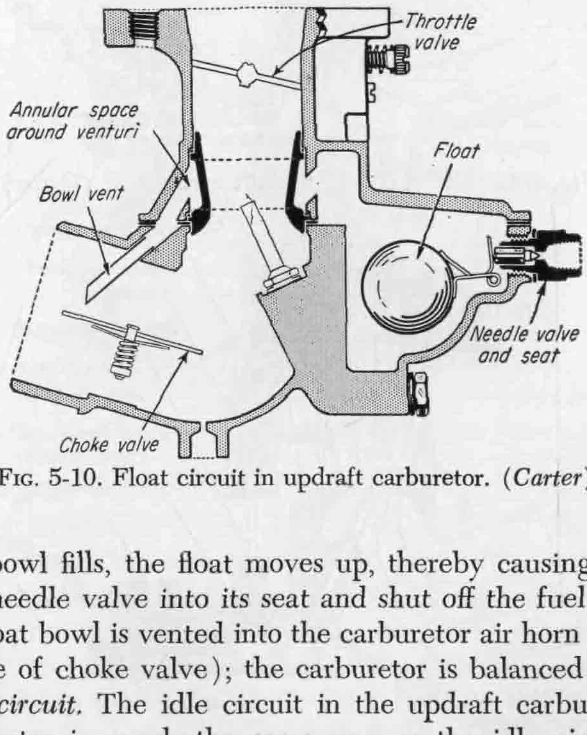


FIG. 5-10. Float circuit in updraft carburetor. (*Carter*)

the float bowl fills, the float moves up, thereby causing the lip to push the needle valve into its seat and shut off the fuel flow. Note that the float bowl is vented into the carburetor air horn (on atmospheric side of choke valve); the carburetor is balanced (see §57).

2. *Idle circuit.* The idle circuit in the updraft carburetor (Fig. 5-11) operates in much the same way as the idle circuit in the downdraft carburetor. It includes an idle-passage tube connecting the float bowl with the idle ports, an idle adjustment screw, idle air bleed, and idle ports. When idling with a closed throttle, fuel is delivered past the pointed tip of the idle adjustment screw. If the throttle valve is opened a little so that its edge moves past the secondary idle port, then it, also, begins to deliver fuel. Air from

the air bleed is mixed with the fuel as it moves upward around the idle-passage tube.

3. *High-speed circuit.* The high-speed circuit in the updraft carburetor (Fig. 5-12) also operates much like the high-speed cir-

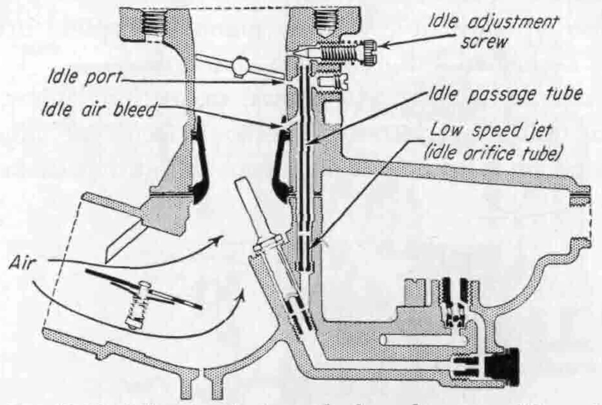


FIG. 5-11. Idle circuit in updraft carburetor. (*Carter*)

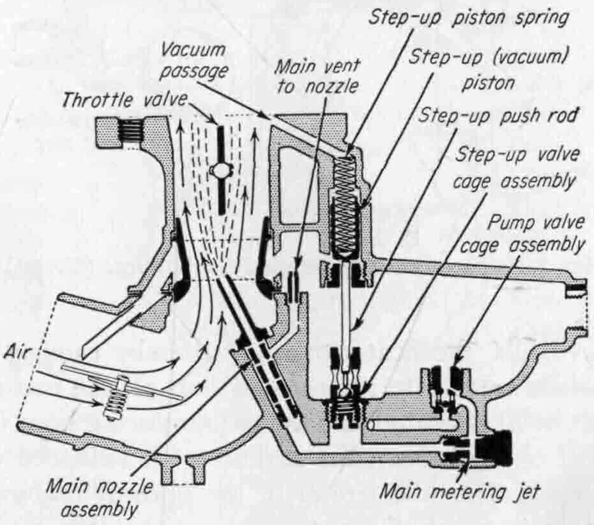


FIG. 5-12. High-speed circuit in updraft carburetor. Arrows represent air flow, dashed lines fuel flow. (*Carter*)

cuit in other carburetors. As the throttle is opened, air flow through the venturi increases. This causes the main nozzle to start discharging fuel. There is a vent from the upper part of the float bowl to the main-nozzle assembly. Air enters the main nozzle through this vent and through a series of holes in the lower end of the main-nozzle tube. Thus, some premixing of air and fuel takes place before the fuel is discharged from the nozzle.

4. *Full-throttle operation.* When the throttle is only partly opened, there is sufficient vacuum in the intake manifold to hold the step-up (vacuum) piston in the upper position. But when the throttle is opened wide, the intake-manifold vacuum drops. This allows the piston spring to push the piston down. The piston push rod then opens the ball valve at its lower end. Additional fuel can then feed past the opened ball valve into the main-nozzle circuit. This gives a richer mixture for full-throttle, full-power operation.

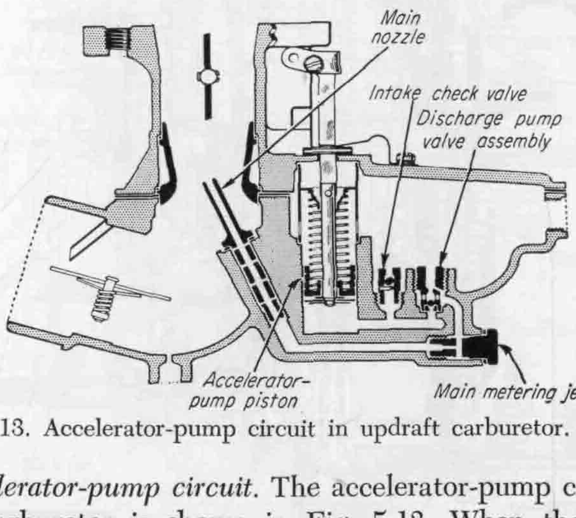


FIG. 5-13. Accelerator-pump circuit in updraft carburetor. (*Carter*)

5. *Accelerator-pump circuit.* The accelerator-pump circuit for an updraft carburetor is shown in Fig. 5-13. When the throttle is closed, linkage to the accelerator-pump piston lifts it upward. This draws fuel from the float bowl past the intake check valve and into the pump chamber below the piston. Then, when the throttle is opened, the piston moves downward. Pressure on the fuel increases, causing the intake check valve to close and the discharge valve to open. Fuel is discharged past the discharge valve under the pressure of the pump-piston spring. This places the fuel in the line to the main nozzle under pressure so that the main nozzle discharges additional fuel.

6. *Idle circuit.* The idle circuit of another type of updraft carburetor is shown in Fig. 5-14. On this unit the idle adjustment screw serves a somewhat different purpose from that of the idle ad-

justment screw on carburetors previously discussed. On this unit the idle adjustment screw admits air into the fuel flowing through the idle circuit from the float bowl. The more air is admitted, the less fuel will flow to the idle discharge port. The fuel flows past the compensating jet and compensating well, up through the idle jet and calibration (or restricting orifice), past the idle adjustment

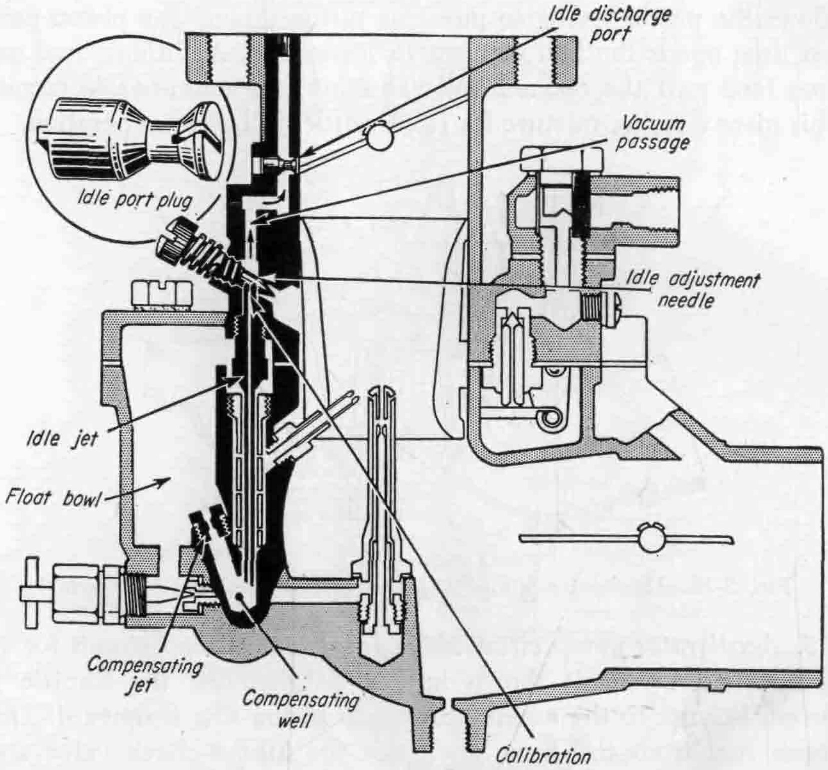


Fig. 5-14. Idle circuit in updraft carburetor. (*Zenith*)

screw and idle-port plug. As the idle adjustment screw is turned in or out, it admits less or more air into the fuel stream. Admitting more air means that less fuel discharges from the idle port, which, in turn, means that the idling mixture is leaner. This idle-adjustment-screw arrangement is used on several models of carburetors, both updraft and downdraft.

7. *Compensating system.* Several carburetor models use a compensating system, which has already been illustrated (Fig. 4-32)

and described (§80). The compensating system tends to lean out the air-fuel mixture as engine speed increases, thereby compensating for the tendency of the main nozzle to enrich the air-fuel mixture as engine speed increases. The combination of compensating system and main nozzle permits the carburetor to supply a properly proportioned mixture for the various operating conditions. Figure 5-15 illustrates the high-speed circuit for a carburetor using a compensating system.

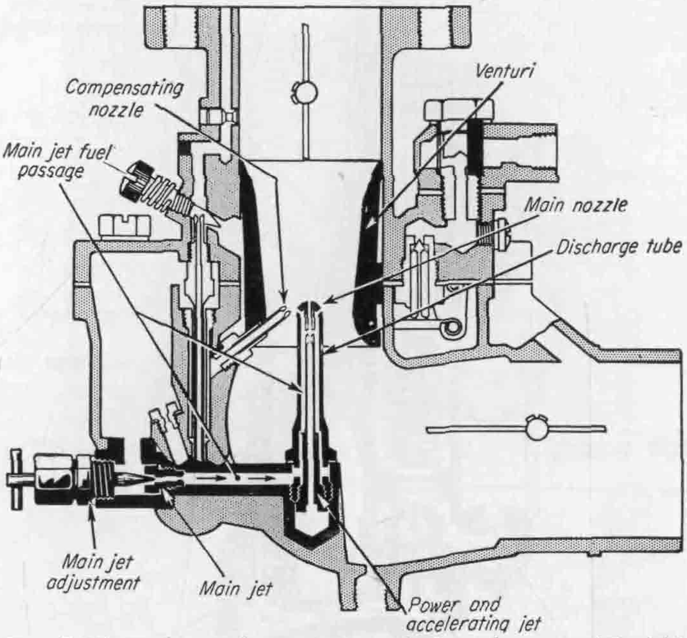


FIG. 5-15. High-speed circuit in updraft carburetor. (*Zenith*)

8. *Accelerator-pump circuit.* Figure 5-16 illustrates the accelerator-pump circuit of the updraft carburetor shown in Figs. 4-32, 5-14, and 5-15. This pump works in much the same manner as accelerator pumps previously described. When the throttle is closed, intake-manifold vacuum, operating through the vacuum passage, draws the vacuum piston upward, compressing the piston spring. This movement lifts the pump piston into the upper part of the pump chamber. Then, when the throttle is opened, intake-manifold vacuum drops, releasing the vacuum piston. The piston spring forces the pump piston downward. The pressure on the

fuel below the pump piston unseats the power valve and allows fuel to flow through it and the power jet to the main nozzle. Extra fuel is thereby discharged from the main nozzle to enrich the mixture for acceleration. The power valve is also held open during open-throttle, low-vacuum conditions; under these conditions, there

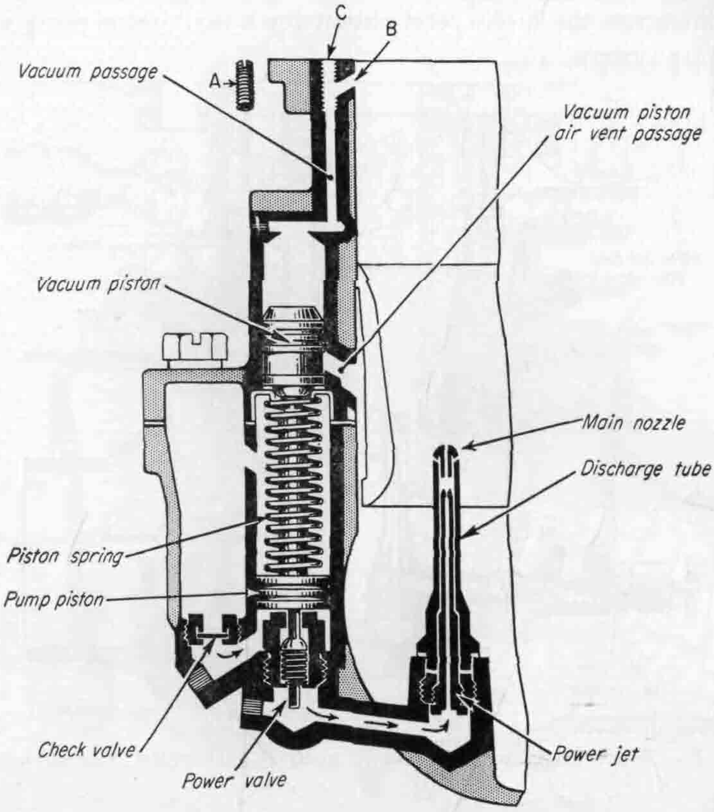


FIG. 5-16. Accelerator-pump and full-power circuit in updraft carburetor. *A*, plug; *B*, vent; *C*, plug opening. (*Zenith*)

is insufficient vacuum in the intake manifold to hold the vacuum piston up. It, along with the pump piston, moves to the bottom position as shown in Fig. 5-16. The pump piston then holds the power valve open. Now, extra fuel can flow past the power valve to the main nozzle for wide-open throttle, full-power operation.

§88. Horizontal air entrance Carburetors of the downdraft type may also have a horizontal air entrance as shown in Fig. 5-17. The carburetor illustrated is a downdraft unit, but the air intake is located at one side in order to save height. The carburetor contains float, idle, low-speed, high-speed, and accelerator-pump circuits similar to those already discussed. Note that the updraft carburetor shown in Fig. 5-17 has horizontal air entrances; updraft carburetors usually have this arrangement.

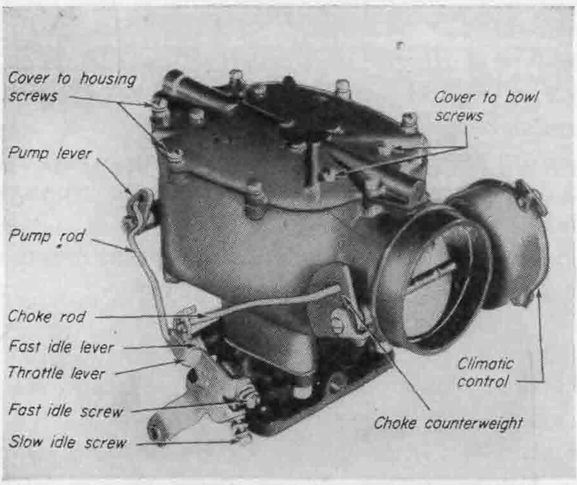


FIG. 5-17. Downdraft carburetor with horizontal air entrance. (*Oldsmobile Division of General Motors Corporation*)

CHECK YOUR PROGRESS

Progress Quiz 3

Here is your progress quiz for the first half of the chapter. The questions below are here to help you. They give you an opportunity to find out how well you are remembering the essential details of the carburetors you have just read about. Also, they help you review the facts you have read, and this review fixes the facts more firmly in your mind. If you have any trouble answering the questions, just reread the pages that will give you the answers. Remember, most good students reread their lessons several times to make sure they won't forget the essential facts in them.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. In order to give the air-fuel mixture more time to burn during part-throttle operation, the ignition distributor must *retard the spark* *increase the spark* *advance the spark* *increase the vacuum*
2. Spark advance based on intake-manifold vacuum does not occur until the throttle *is fully closed* *is wide open* *opens a small amount*
3. Automatic-type starting-control-switch action is based on both intake-manifold vacuum and *throttle movement* *engine speed* *choke position*
4. Throttle-return checks are used on some cars equipped with *dashpots* *power steering* *automatic transmissions* *power brakes*
5. The device installed on some vehicles to prevent overspeeding of the engine is called a *speeder* *governor* *control brake*
6. The velocity-type governor is installed between the carburetor and the *intake manifold* *exhaust manifold* *air cleaner* *throttle valve*
7. In the velocity governor the throttle plate tends to move toward the closed position as the velocity of the air-fuel mixture through the carburetor air horn *decreases* *increases* *strikes a balance*
8. Carburetors may be divided, according to the direction of air flow through the air horn, into *downdraft and updraft* *forced draft and free draft* *horizontal draft and vertical draft*
9. In some carburetors the idle adjustment screw admits air-fuel mixture into the air horn; in others, it admits air into the *main-nozzle circuit* *updraft* *idle circuit* *high-speed circuit*
10. The main purpose of the compensating system is to compensate for variations in fuel flow from the *idle circuit* *low-speed circuit* *main nozzle*

§89. Dual carburetors In eight-cylinder in-line and V-8 engines it is common practice to use a dual carburetor with dual-type intake manifolding. In a dual carburetor there are two separate air horns (or barrels), two venturis, two main fuel nozzles, and two throttle valves. The two throttle valves are attached to a common throttle shaft so that both valves open and close together. Figures

4-3, 4-11, and 5-5 are different views of dual carburetors. The dual carburetor provides, in effect, two separate single-barrel carburetors, each carburetor feeding four of the cylinders. Each carburetor barrel feeds into one section of a dual-type intake manifold. Figure

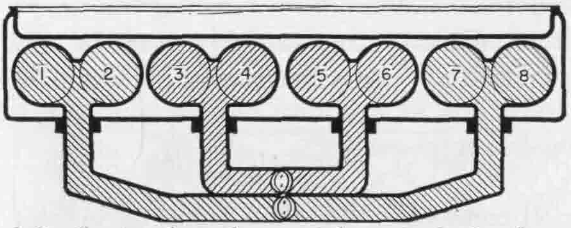


FIG. 5-18. Fuel distribution through two air horns in dual carburetor and intake manifolds on an eight-cylinder in-line engine. (*Buick Motor Division of General Motors Corporation*)

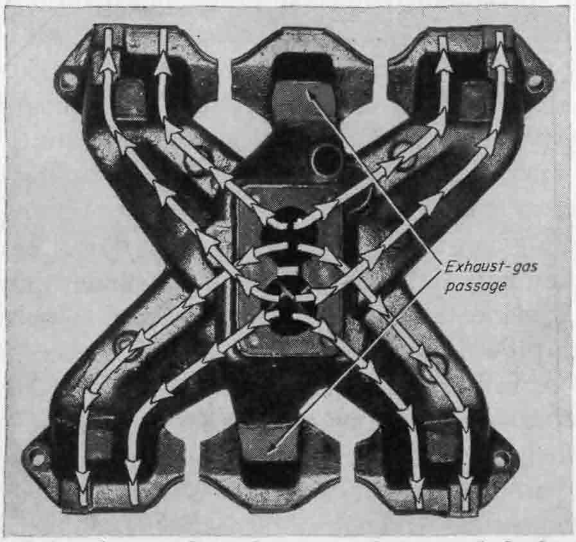


FIG. 5-19. Fuel distribution through two air horns and dual-intake-manifold system of dual carburetor on V-8 engine. (*Studebaker Corporation*)

5-18 shows the air-fuel-mixture delivery pattern for an eight-cylinder in-line engine. One carburetor barrel supplies cylinders 3, 4, 5, and 6. The other carburetor barrel supplies cylinders 1, 2, 7, and 8. The delivery pattern for a V-8 engine is shown in Fig. 5-19. In this pattern, each carburetor barrel supplies two cylinders in each bank as indicated by the arrows. This arrangement assures greater uniformity of fuel delivery to all cylinders. If a single barrel were used to supply all eight cylinders, the most distant cylinders would get less air-fuel mixture than the nearby cylinders. The end cylinders in an in-line engine, for example, would be starved. Inferior engine performance would result. But by using a two-barrel, or dual, carburetor, the intake manifolding can be arranged so that all cylinders being fed from a barrel will be about equally distant from the barrel. Thus, all cylinders receive approximately the same amounts of air-fuel mixture.

§90. Four-barrel carburetor The four-barrel carburetor (Figs. 5-21 to 5-25) consists, in effect, of two dual carburetors combined into a single assembly. The carburetor assembly has four air horns, or barrels, each with its own venturi, throttle valve, and main fuel nozzle. Since it has four barrels, and thus four main nozzles, or fuel jets, it is often called a *quadrijet carburetor*. One set of air horns, or barrels, makes up a primary dual carburetor. The other pair makes up a secondary dual carburetor. The primary dual carburetor is responsible for delivery of air-fuel mixture to the engine under most operating conditions. The primary dual carburetor, or *primary side*, as it is called, contains a full complement of circuits, including idling-and-low-speed circuit, high-speed circuit, accelerator-pump circuit, and choke circuit. Thus, under most operating conditions, it alone takes care of engine requirements. However, when the throttle is moved toward the wide-open position for acceleration or full-power operation, then the secondary dual carburetor, or *secondary side*, comes into operation and supplies additional air-fuel mixture. This combination permits satisfactory and economical part-throttle operation. At the same time, improved full-throttle operation is attained, since with wide-open throttle, the passage space for air-fuel mixture to enter the engine is doubled (from two to four barrels). Greater amounts of air-fuel mixture can enter the engine for improved high-speed, full-power performance. The following paragraphs describe the features of this carburetor.

1. *Manifold.* Since there are four barrels in this carburetor, the intake manifold must have four openings at the carburetor mounting pad, two for the primary-side barrels and two for the secondary-

side barrels (Fig. 5-20). When the primary side only is in operation, then the two openings (marked *P* in the illustration) deliver air-fuel mixture to the cylinders. One handles cylinders 1, 4, 6, and 7. The other handles cylinders 2, 3, 5, and 8. When the secondary side comes into operation, its two barrels augment the air-fuel-mixture delivery of the primary-side barrels. Delivery patterns are shown by long arrows (primary side) and short arrows (secondary side) in the illustration.

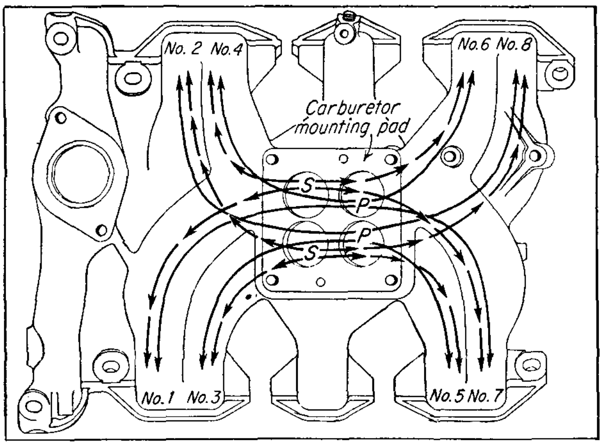


Fig. 5-20. Intake manifold for four-barrel carburetor. *P* indicates the primary barrels. Air-fuel-mixture delivery from these is shown by long arrows. S indicates the secondary barrels. Air-fuel-mixture delivery from these is shown by short arrows. (*Oldsmobile Division of General Motors Corporation*)

2. *Float circuit.* Figure 5-21 illustrates the float circuit of the carburetor assembly. The primary and secondary sides of the assembly (each consisting of two barrels) have their own float circuits with separate float assemblies and needle valves. The two float bowls are separated by a partition, but both vent into the carburetor air horn. A connecting passage between the two float bowls permits the fuel levels and air pressures to balance between the two float bowls.

3. *Low-speed circuit.* During part-throttle operation, the primary dual carburetor (or primary side) functions in the same way as a standard dual carburetor (§89). Delivery pattern of the air-fuel mixture to the cylinders is as shown by long arrows in Fig. 5-20. The idle-and-low-speed circuit of the carburetor is shown in Fig.

5-22. This illustration shows the primary and secondary sides separated so the circuits can be seen. Actually, they are one assembly as shown in Fig. 5-21 or 5-24. Note that, on the carburetor model illustrated, the secondary side has a fixed idle circuit. A fixed amount of air-fuel mixture can discharge through it. The primary side has standard adjustable idle circuits (one for each barrel). Adjustment can be made on the primary side alone (by

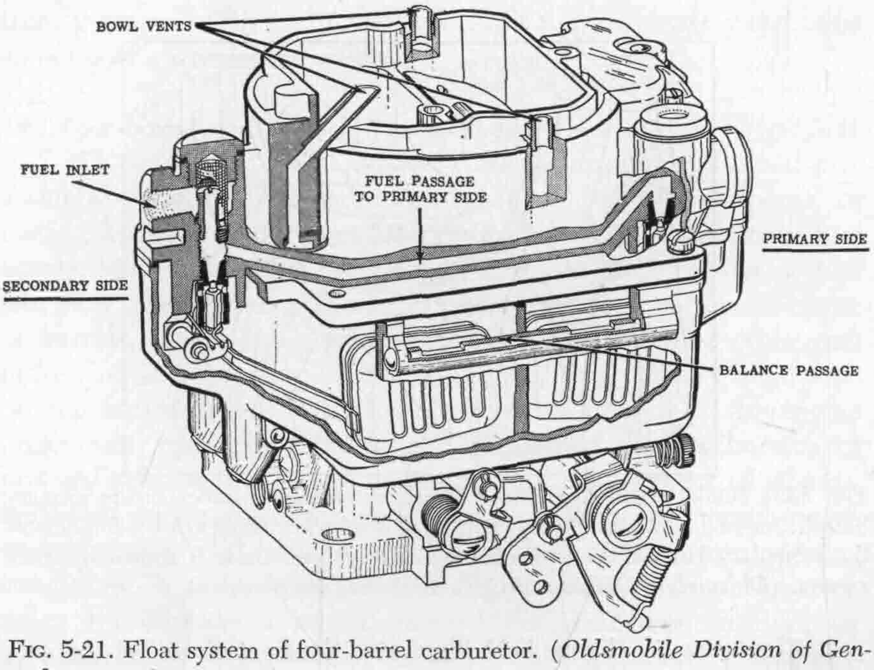


FIG. 5-21. Float system of four-barrel carburetor. (*Oldsmobile Division of General Motors Corporation*)

turning the idle adjustment screw) to provide correct idle-mixture richness.

Other carburetors of this type do not have any idle or low-speed ports or circuits in the secondary side. On these, the primary side alone supplies fuel for idling and low-speed operation.

The carburetor contains a vapor-vent ball check that opens as the accelerator-pump countershaft returns to the closed-throttle position. Opening of the vapor-vent ball check provides a vent through which fuel vapors can escape from the float bowls so that percolation will not occur (see §78).

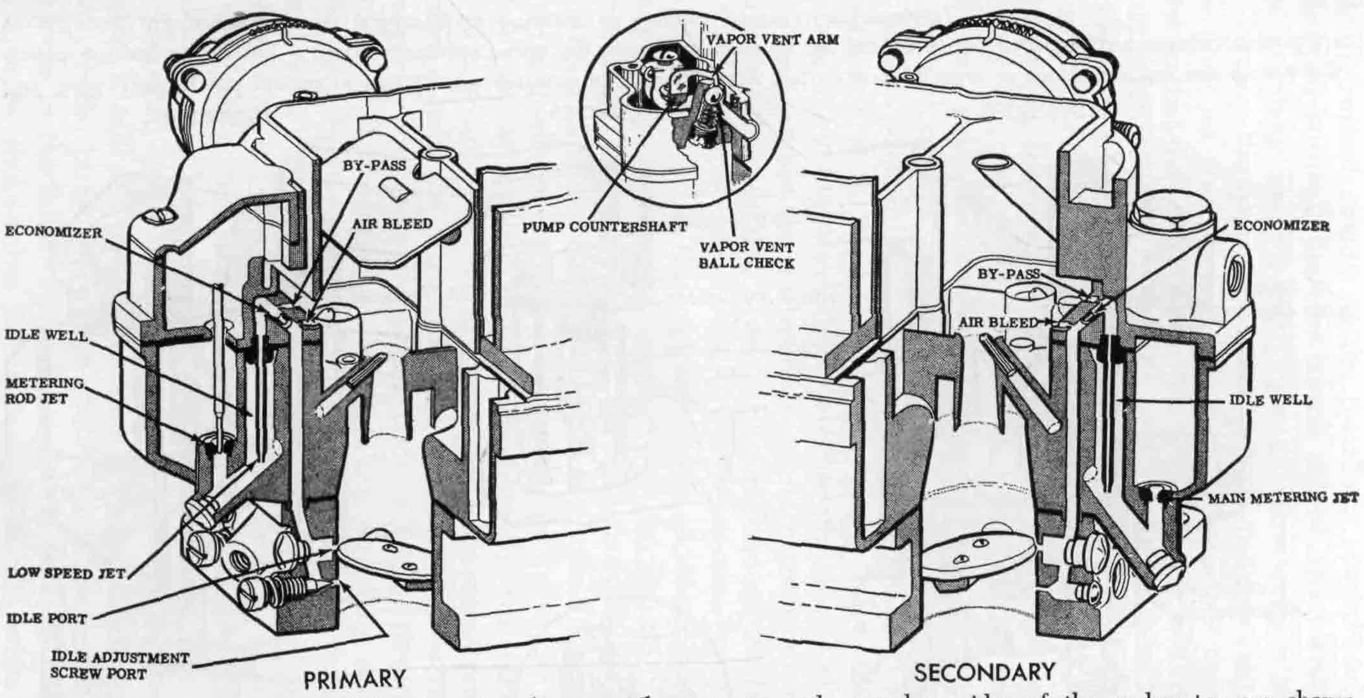


FIG. 5-22. Low-speed circuit of four-barrel carburetor. The primary and secondary sides of the carburetor are shown separated although, in actuality, they are side by side. Note that the secondary side has idle ports. Other models of this type of carburetor do not have idle ports on the secondary side. (*Oldsmobile Division of General Motors Corporation*)

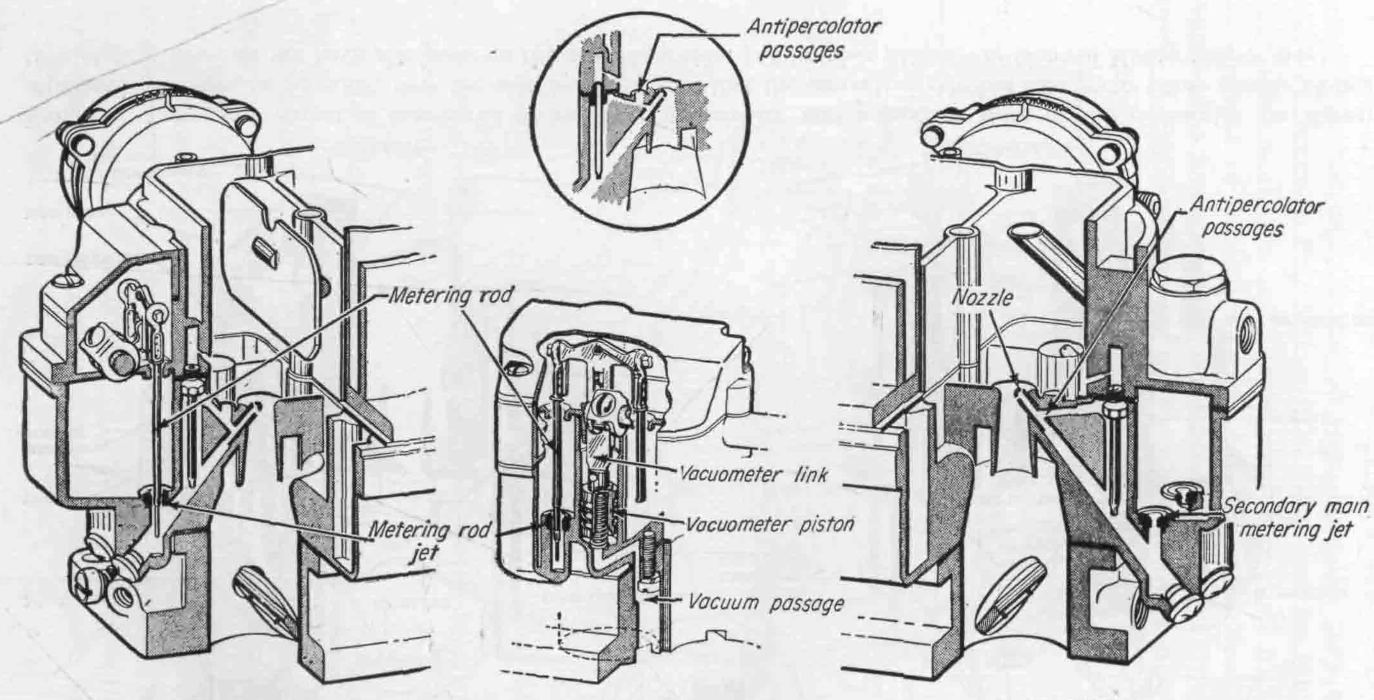


FIG. 5.23. High-speed circuit of four-barrel carburetor. The primary and secondary sides of the carburetor are shown separated although they are actually assembled side by side. The view in the center shows in detail the construction of the vacuumeter full-power circuit. (*Oldsmobile Division of General Motors Corporation*)

4. *High-speed circuit.* As the throttle is opened and nears the wide-open position, the two barrels on the secondary side come into operation. The secondary throttle valves remain closed until the primary throttle valves near the wide-open position. But from that point on, they open rapidly with little further throttle movement so that they reach wide-open position along with the primary throttle valves. With all throttle valves open, the condition shown in Fig. 5-23 results. Now, air-fuel mixture is delivered through all four barrels (see Fig. 5-20). Fuel flows from the secondary nozzles after passing through fixed metering jets and fuel passages. On the primary side, fuel delivery is through a combination mechanically operated and vacuum-operated type of high-speed, full-power circuit with metering rods controlled by a vacuum piston as well as by throttle position (§67). The metering rods are lifted either when the throttle is in the wide-open position or when there is little vacuum in the intake manifold. In either case, lifting of the metering rods positions the smaller diameter of the rods in the metering-rod jets so that additional fuel is delivered through the fuel nozzles.

5. *Accelerator-pump circuits.* The accelerator-pump circuit is shown in Fig. 5-24. This circuit supplies additional fuel for acceleration in the lower speed ranges. When the throttle is opened for acceleration, the pump plunger is forced down by linkage to the throttle. This action forces fuel out through the discharge passage, past the discharge check, and through the pump jet into the passing air stream. At higher speeds, no accelerator-pump action is necessary for smooth acceleration. To prevent accelerator-pump action at higher speeds, the plunger linkage is so arranged as to cause the plunger to bottom in the pump cylinder when the throttle has been opened a predetermined amount. Thus, no pump action results when the throttle is opened still wider. Note that the accelerator-pump circuit is in the primary side. The secondary side has no such circuit.

6. *Choke circuit.* The choke circuit is shown in Fig. 5-25. Note that there is a choke valve on the primary side only. The choke valve is positioned by the thermostatic spring so that it is closed when the engine is cold and open when the engine is hot. During warm-up, the vacuum piston also helps to determine choke-valve position. Vacuum in the intake manifold causes the vacuum piston to tend to open the choke valve. But during acceleration, when the intake-

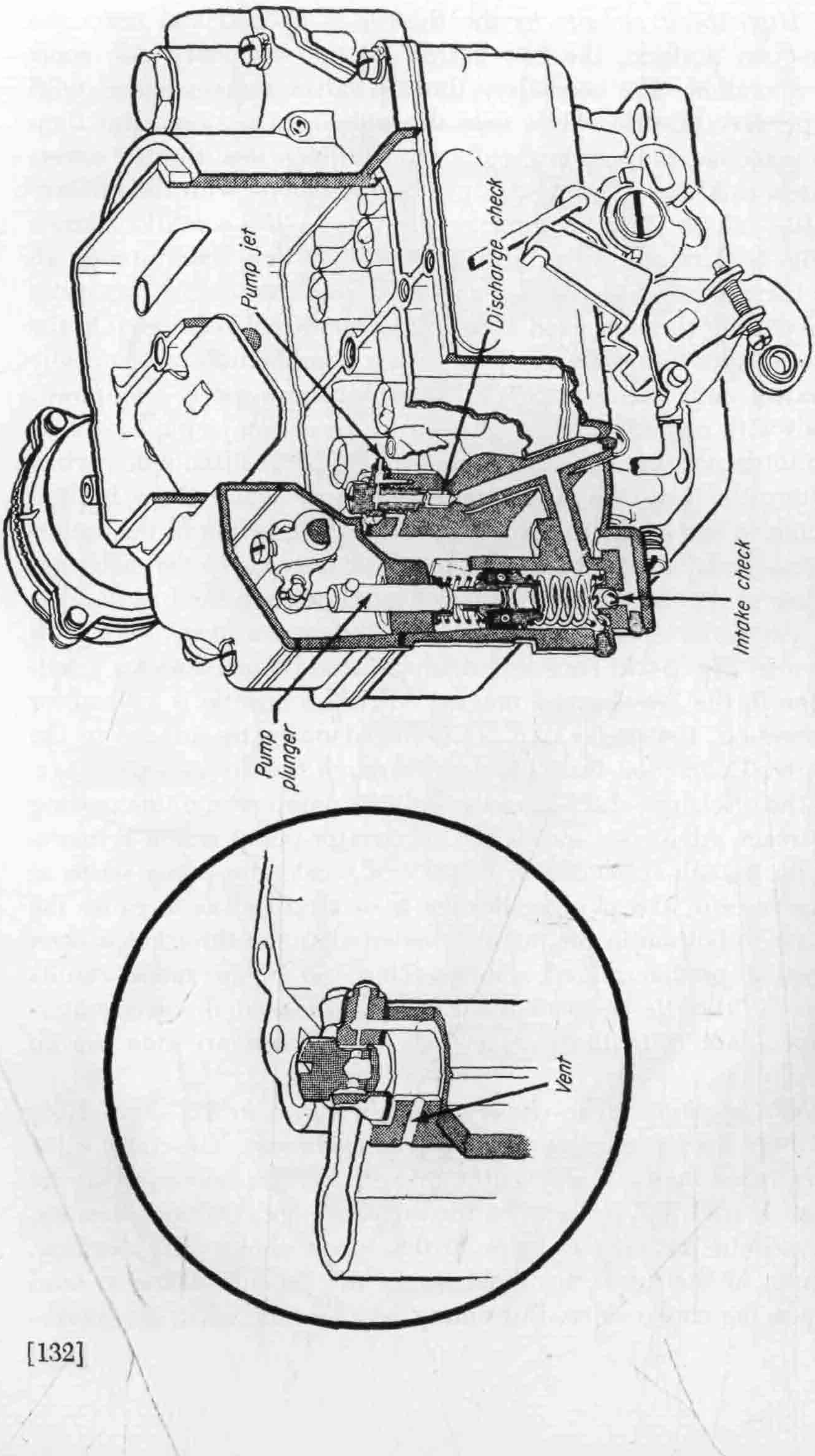


FIG. 5-24. Accelerator-pump circuit of four-barrel carburetor. The pump discharges into the two barrels on the primary side only. (*Oldsmobile Division of General Motors Corporation*)

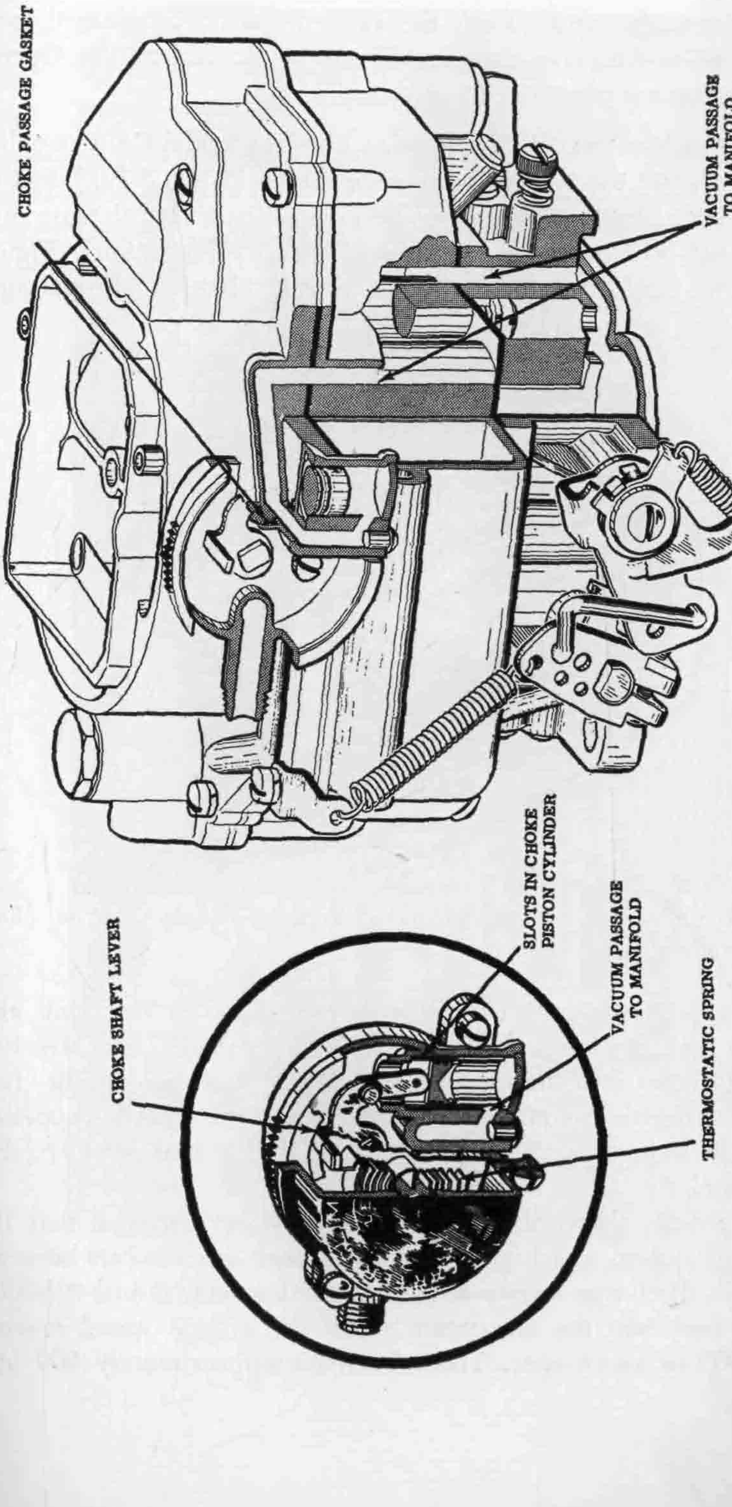


FIG. 5-25. Choke circuit of four-barrel carburetor. (*Oldsmobile Division of General Motors Corporation*)

manifold vacuum is reduced, the vacuum piston is released, permitting the choke valve to move toward the closed position. Operation of automatic chokes is covered in §72.

§91. Ford carburetors *1. Six cylinder.* The late-model Ford six-cylinder engines use the type of carburetor shown in Fig. 5-26. This carburetor is interesting because of its compactness and the use of a transparent float-bowl cover (on left side in illustration). Figure 5-27 shows the carburetor partly cut away so that the idle passages

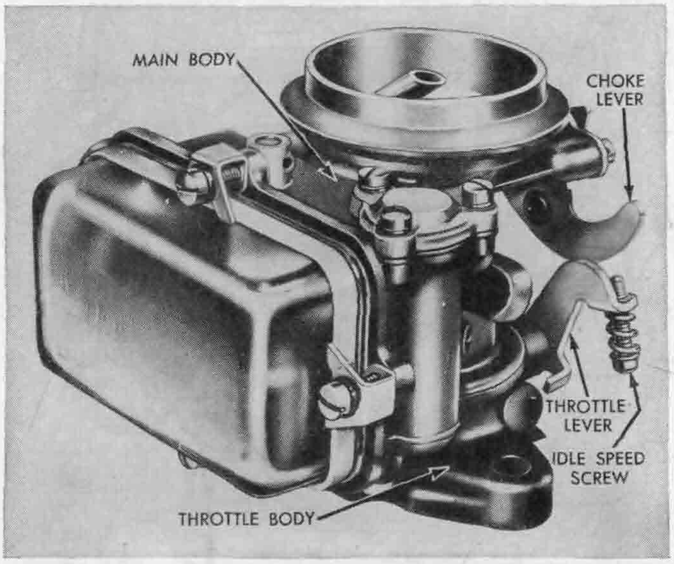


FIG. 5-26. Carburetor used on late-model Ford six-cylinder engines. (*Ford Motor Company*)

can be seen. Note the air bleed from the upper air horn and also the fact that the carburetor uses a single venturi. There are two discharge holes into the air horn, the lower of which supplies fuel when the throttle is completely closed. When the throttle is opened slightly, it swings past the upper hole so that it also begins to discharge fuel.

Figure 5-28, shows the carburetor partly cut away so that the main fuel system and high-speed, full-power circuits can be seen. The main discharge nozzle is located in the venturi and it begins to feed fuel into the air stream when the engine speed reaches about 900 or more rpm. Then, between approximately 900 and

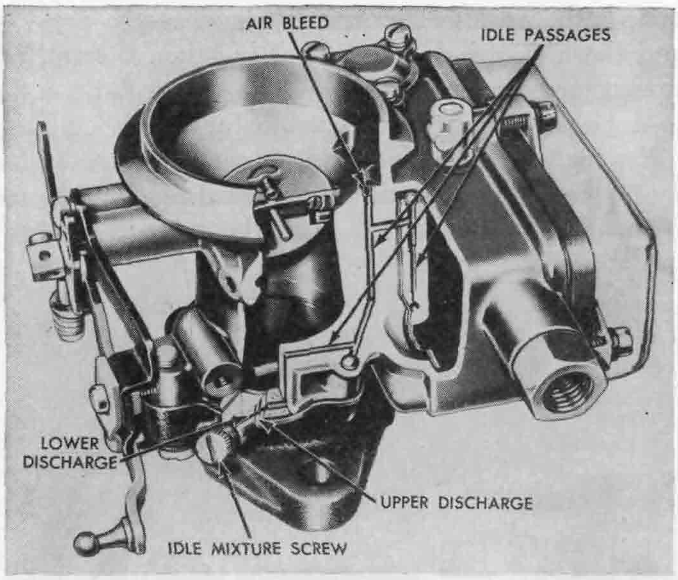


FIG. 5-27. Carburetor cut away to show idle circuit. (*Ford Motor Company*)

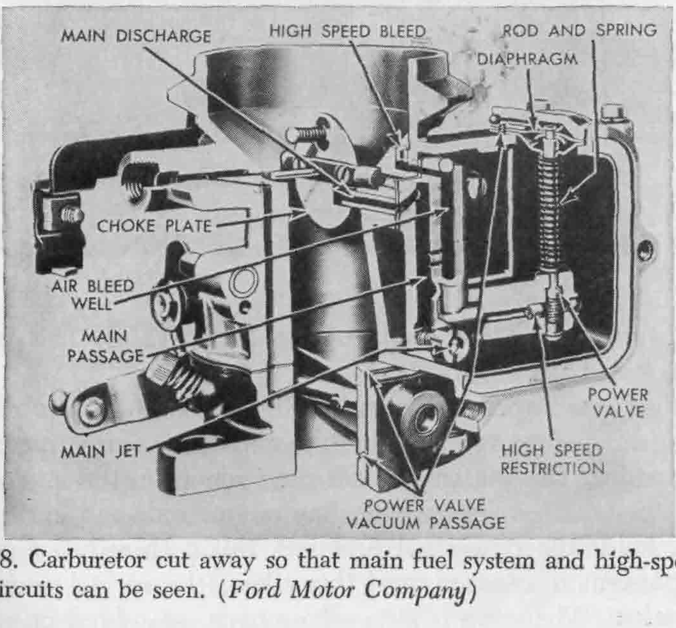


FIG. 5-28. Carburetor cut away so that main fuel system and high-speed, full-power circuits can be seen. (*Ford Motor Company*)

1,250 rpm, both the idle circuit mentioned in the previous paragraph and the high-speed circuit work together to supply the fuel. As the speed increases still more, the idle circuit fades out, and the high-speed circuit alone is responsible for supplying fuel to the engine. The high-speed air bleed introduces air into the fuel passing through the high-speed circuit before it reaches the main discharge. The fuel is discharged from the main discharge nozzle

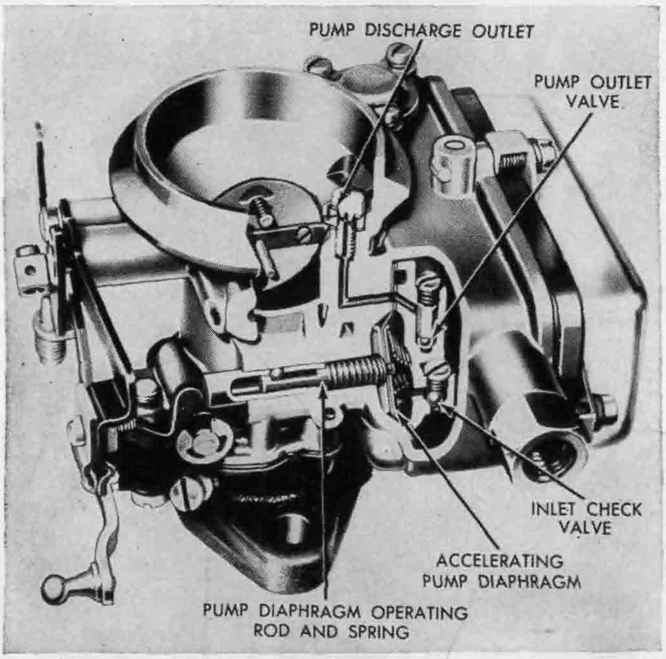


FIG. 5-29. Carburetor cut away so accelerating system can be seen. (*Ford Motor Company*)

directly against the lower side of the choke valve. This helps to vaporize it and mix it with the passing air.

For high-speed operation or under heavy load, as when climbing a hill, additional power is desirable, and this means opening the throttle wider. This action reduces the vacuum in the intake manifold. With a high vacuum, the diaphragm, rod, and spring combination holds the power valve closed. But with reduced vacuum, the diaphragm is released, and this allows the spring to open the power valve. When the power valve opens, an added passage for fuel is opened in the high-speed circuit. Additional fuel is supplied to handle the added power demand of the high-speed or heavy-load operation.

Figure 5-29 shows the carburetor cut away so that the accelerating system can be seen. When the throttle is opened for acceleration, the operating rod and spring impose pressure on the diaphragm. The diaphragm therefore moves, forcing fuel in the pump chamber out past the outlet valve, through the drilled passage, and through the pump discharge outlet. When the throttle

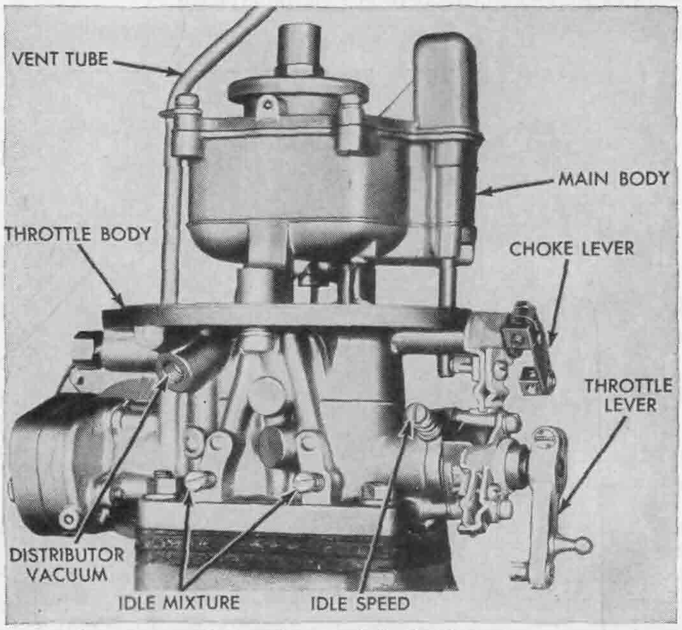


FIG. 5-30. Carburetor used on late-model Ford V-8 engines. (*Ford Motor Company*)

is released, the diaphragm spring returns the diaphragm to its original position. Additional fuel is drawn into the pump chamber past the inlet check valve.

2. *Eight-cylinder carburetor.* A late-model carburetor for a Ford V-8 engine is shown in Fig. 5-30. This is a dual carburetor (two barrels) designed to use an air cleaner that mushrooms over and surrounds the main body. The construction gives the carburetor a somewhat different appearance, but it operates in essentially the same manner as other dual carburetors. Figure 5-31 shows how the carburetor air cleaner is assembled on the carburetor.

Figure 5-32 shows the carburetor cut away so that the idle circuit can be seen. The fuel passes through the main jet and idle passage to the discharge holes at the throttle valves. Each barrel has its own discharge holes, feeding from the common idle passage in the main body. Note that there is an idle-air-bleed opening in the main body. When the throttle is closed, fuel feeds through the lower discharge opening only, past the idle-mixture screw. But when the throttle is opened a little, it swings past the upper discharge hole so that it also begins to discharge fuel into the air stream.

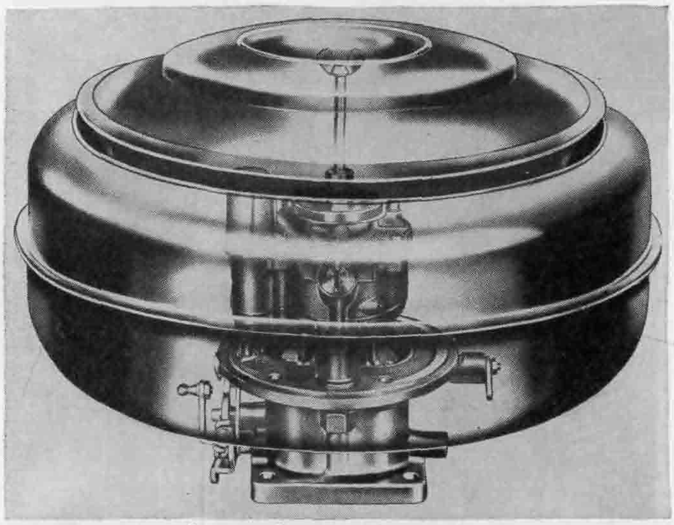


FIG. 5-31. Phantom view showing how air cleaner sits down over the carburetor, so that the main body of the carburetor is actually located inside the air cleaner. (*United Specialties Company*)

The main power circuit is shown in Fig. 5-33. The fuel passes through the main jet from the float bowl, up through the main well and down through the two main discharge nozzles into the two barrels of the carburetor. The main well contains an air bleed at its upper end.

For full-power, high-speed operation the throttle is moved toward the wide-open position. This causes a loss of vacuum in the intake manifold. With a high vacuum, the diaphragm holds the power valve up in the closed position. But when the throttle is opened so that vacuum is reduced, the diaphragm moves downward under spring pressure, permitting the power valve to open. Now, increased fuel can flow through the power-valve restriction and into the main well. Additional fuel is therefore delivered from the well by the main nozzles to handle the added power demands.

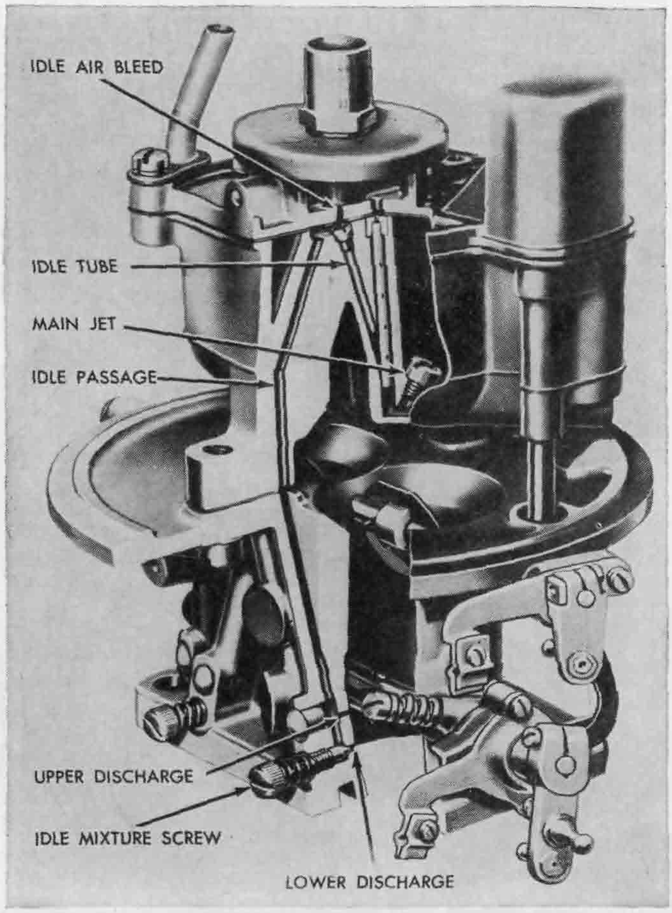


FIG. 5-32. Carburetor cut away so the idle circuit can be seen. (*Ford Motor Company*)

Figure 5-34 shows the accelerating system of the carburetor. The carburetor uses a pump piston which is linked to an operating rod to the throttle. When the throttle is opened for acceleration, the pump piston is forced downward, causing a discharge of fuel from the pump outlet into the barrels.

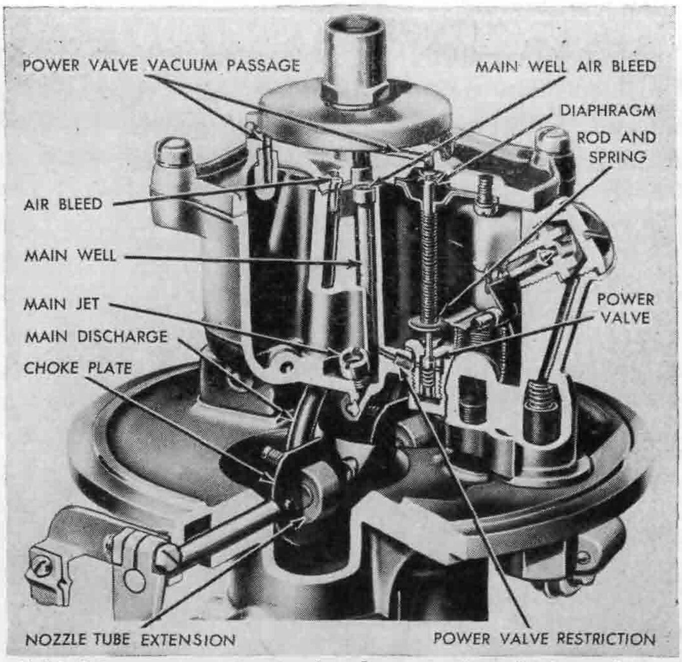


FIG. 5-33. Main power circuit of carburetor. (*Ford Motor Company*)

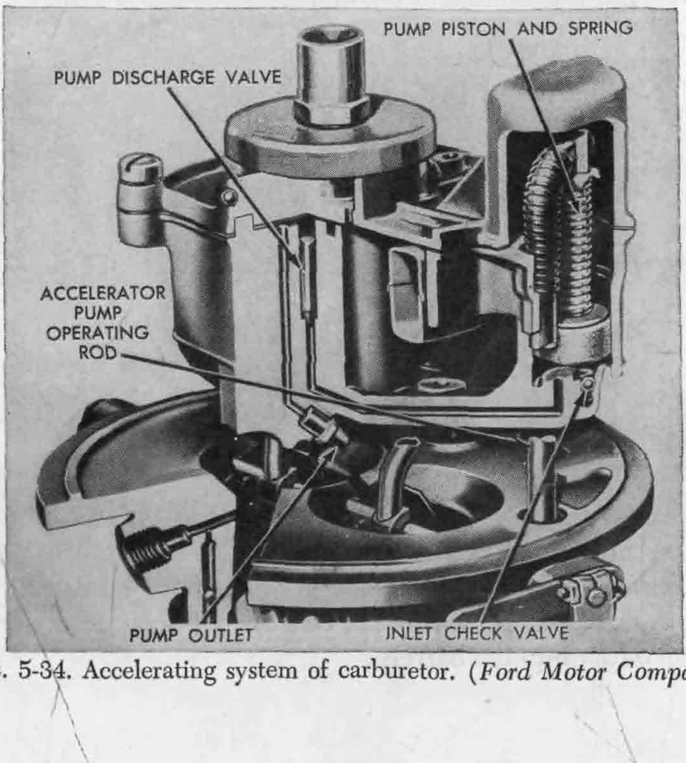


FIG. 5-34. Accelerating system of carburetor. (*Ford Motor Company*)

§92. Multiple-carburetor installations For additional performance, it is possible to install more than one carburetor on an engine. On racing engines and other applications where maximum possible performance is desired, there may actually be one carburetor for each cylinder. This, however, is unusual. For automotive applications,

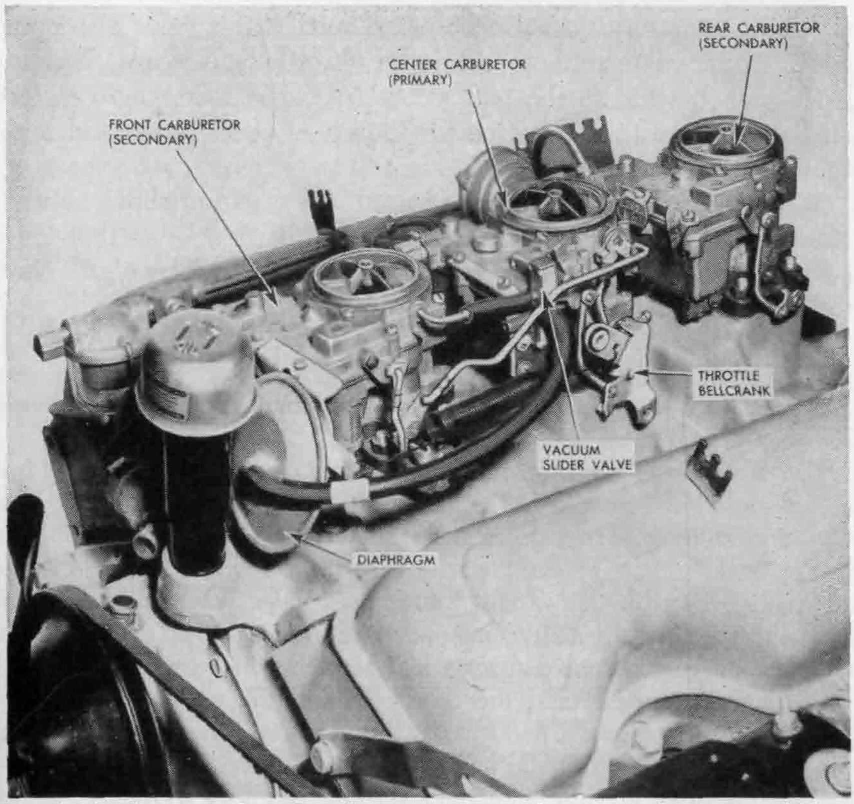


FIG. 5-35. Three two-barrel carburetors mounted on a single engine. (*Chevrolet Motor Division of General Motors Corporation*)

two or three carburetors may be installed on one engine. For example, Fig. 5-35 shows a three-carburetor installation on a Chevrolet V-8 engine. A special intake manifold is required on which the three carburetors can be mounted. The three carburetors are interconnected by mechanical and vacuum linkage. The center or primary carburetor supplies all fuel when the throttle is less than 60-degrees open. When the throttle is opened beyond 60 degrees, the linkage opens a vacuum slider valve mounted on the center carburetor.

Vacuum from the vacuum pump (an integral part of the fuel pump) is now applied to the large diaphragm mounted on the front secondary carburetor. This diaphragm, therefore, is forced to move and this movement is transmitted to the throttle valve of the front carburetor by a rod. The throttle valve of the front carburetor then opens wide. This same movement is transmitted to the rear secondary-carburetor throttle valve by a rod so that this valve also opens wide. The two secondary-carburetor throttle valves are therefore both opened wide so the two secondary carburetors begin to feed air-fuel mixture to the engine for improved acceleration and high-speed performance.

When the throttle valve is released, the vacuum slider valve is closed. This shuts off the vacuum to the diaphragm so that it relaxes and the two secondary carburetor throttle valves close. Now, the system performs as a single-carburetor system.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You are making excellent progress in your studies of automotive fuel systems and have completed the part of the book dealing with the operation of gasoline-type fuel systems. The material you have studied thus far in the book will be of considerable help to you when you go into the automotive shop or office. This information helps you understand how and why the fuel system components operate as they do. The later chapters on fuel-system diagnosis and service will be much easier for you when you understand the theory behind the units you work on. The general checkup test that follows will help you review and remember the essential facts you should know about carburetors. Write the answers to the questions in your notebook. Writing the answers helps you remember them and also makes your notebook a valuable source of information to which you can refer in times of need.

Unscrambling the Devices

When the two lists below are unscrambled and combined, they will form a list of the various devices used on carburetors and the applications or purposes of these devices. To unscramble the lists, take one item at a time from the list to the left, and then find the item from the list to the right that goes with it. For an example of how this is done, refer to "Unscrambling the Jobs" at the end of Chap. 3, "Fuel-System Operation." Write the list down in your notebook.

Automotive Carburetors

vacuum circuits	for shifting to lower transmission gear
electric switches	to control or limit top engine speed
throttle-return checks	for starting-motor control
kick-down switches	for ignition-distributor spark advance
governors	for cars with automatic transmissions

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Many carburetors have a special vacuum circuit that is connected to the *fuel pump* *fuel tank* *fuel gauge* *ignition distributor*
2. Some carburetors have a special electric switch that is connected into the *light circuit* *starting-motor control circuit* *air-horn circuit*
3. Some carburetors contain a special dashpot, or check, that *retards throttle opening* *retards throttle closing* *shifts gears*
4. The kick-down switch used on some carburetors has the job of producing *lower speed* *higher vacuum* *throttle retard* *transmission downshift*
5. Two types of governor are *centrifugal and velocity* *dashpot and electric* *kick-down and vacuum* *speed and down-shifting*
6. There are two separate arrangements of the idle circuit and idle adjustment screw. In one, air-fuel mixture flows past the screw into the air horn; in the other, *air flows past screw into idle circuit* *air flows past screw to venturi* *air flows past screw to main nozzle*
7. In the dual carburetor there are two separate *exhaust valves* *intake valves* *throttle valves* *intake manifolds*
8. The most important function of the secondary side in the four-barrel carburetor is to *improve wide-open-throttle performance* *improve acceleration at part throttle* *improve low-speed performance*
9. The Ford six-cylinder carburetor has *one barrel* *two barrels* *four barrels*
10. The Ford V-8 carburetor described in the book has its upper part completely surrounded by *the float bowl* *the air cleaner* *the main venturi* *the secondary venturi*

Purpose and Operation of Components

In the following, you are asked to write down the purpose and operation of certain carburetor accessory devices discussed in the chapter. If you have any difficulty in writing down your explanations, turn back into the chapter and reread the pages that will give you the answer. Don't copy, try to tell it in your own words. This is an excellent way to fix the explanation firmly in your mind. Write in your notebook.

1. What is the purpose of the vacuum-controlled mechanism in the ignition distributor?
2. Explain how the starting control switch described in the chapter operates.
3. What is the purpose of the throttle-return check?
4. What is the purpose of the governor?
5. List the various circuits of the updraft carburetor as explained in the chapter.
6. What is the reason for using a two-barrel, or dual, carburetor?
7. What is the function of the secondary side of the four-barrel carburetor?
8. List the circuits in the primary side of the four-barrel carburetor; in the secondary side.

SUGGESTIONS FOR FURTHER STUDY

Refer to other books in the McGraw-Hill Automotive Mechanics Series (*Automotive Electrical Equipment* and *Automotive Transmissions and Power Trains*) for additional information on electric units and automatic transmissions referred to in the chapter. You can also find out more about these units in your school shop or in a friendly service shop. Possibly you will be able to borrow car manufacturers' manuals from your school automotive shop library or from a service shop. Such manuals have much valuable information in them about the electric units and automatic transmissions and explain the manner in which the various units are tied into the carburetor. Be sure to write down in your notebook all the important facts you come across.

6: Fuel injection and LPG fuel systems

IN PREVIOUS chapters, we have discussed carburetor fuel systems; these are the most widely used automotive fuel systems. However, there are other fuel systems; these are considered in this chapter. They include the fuel-injection system which has several variations and the LPG fuel system. Fuel-injection systems are used on both gasoline engines and diesel engines.

§93. Gasoline fuel-injection systems Some automobiles are now equipped with a fuel-injection system instead of a carburetor fuel

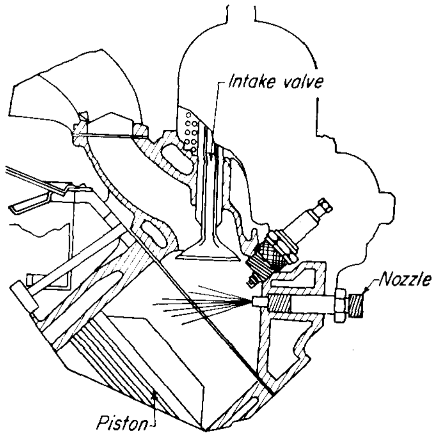


FIG. 6-1. Simplified view showing method of injecting fuel directly into combustion chamber of engine.

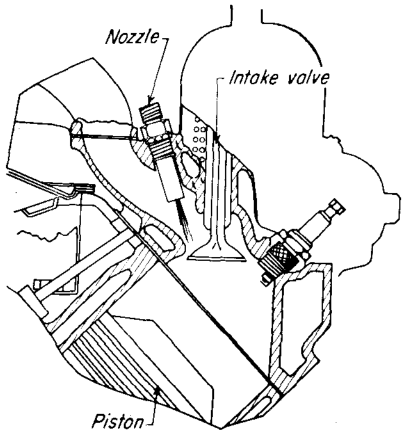


FIG. 6-2. Simplified view showing method of injecting fuel into intake manifold just back of the intake valve.

system. There are two basic types of fuel injection systems. In one, the fuel is injected directly into the combustion chamber (Fig. 6-1). In the other, the fuel is injected into the intake port behind the intake valve (Fig. 6-2). The latter system is simpler and is the one generally used in automotive applications. It is described in the following paragraphs.

§94. Ramjet fuel-injection system The major components of this system are shown in Fig. 6-3. It consists essentially of a special intake manifold, an air meter, and a fuel meter. The air meter controls the flow of air through the intake manifold to the engine cylinders. The fuel meter controls the flow of fuel to the injection nozzles in the intake manifold. The system is simple; linkage from the accelerator

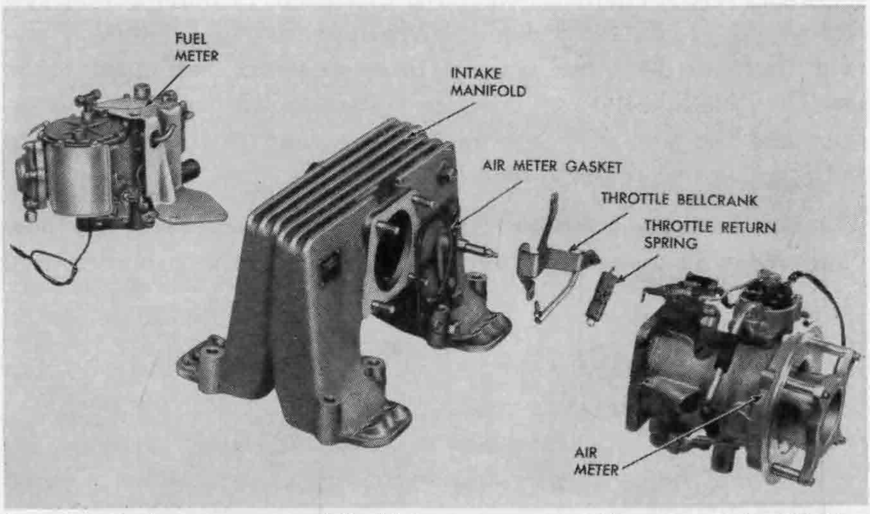


FIG. 6-3. Basic components of fuel-injection system. (*Chevrolet Motor Division of General Motors Corporation*)

pedal actuates a throttle valve in the air meter; more air is admitted when more engine power is desired. The fuel meter operates to provide varying amounts of fuel; it supplies more fuel as more air is admitted.

Other mechanisms enrich the mixture for acceleration, warm-up, hill climbing, and so on. Figure 6-4 is a sectional drawing of the complete system.

§95. Air intake The air intake of the system is shown in Fig. 6-5. The amount of air that enters is controlled by the throttle valve (see Fig. 6-4) which is located in the throat of the air meter. The throttle valve is connected by linkage to the acclerator pedal, just

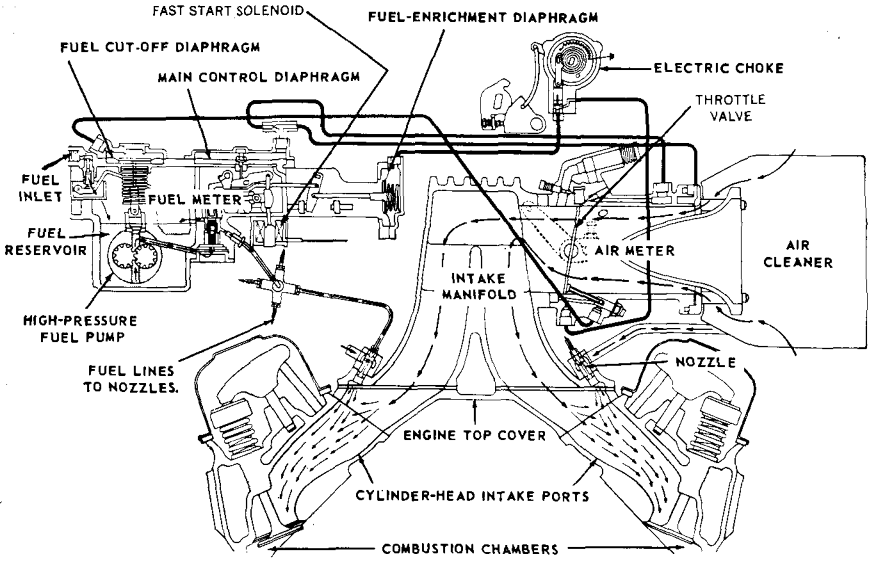


Fig. 6-4. Sectional view of complete fuel-injection system. (*Chevrolet Motor Division of General Motors Corporation*)

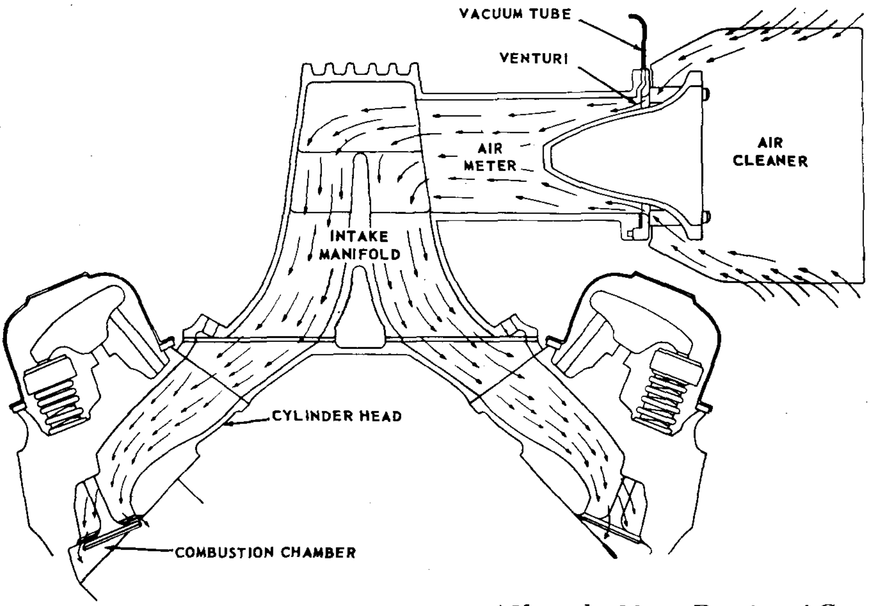


Fig. 6-5. Air intake of fuel-injection system. (*Chevrolet Motor Division of General Motors Corporation*)

as the throttle valve in the carburetor. As the throttle valve is opened, more air flows into the intake manifolds and engine cylinders. A vacuum tube, connected at a venturi at the air cleaner end of the air meter, "senses" the amount of air entering. When only a little air is entering, then there is only a little vacuum applied to the vacuum tube. But when considerable air enters, then more vacuum develops at the venturi and is applied to the tube. This varying vacuum is used to control the amount of fuel the fuel meter delivers to the injection nozzles in the intake manifold.

§96. Fuel intake The essential parts of the fuel-intake system are shown in Fig. 6-6. The regular engine fuel pump sends fuel into a

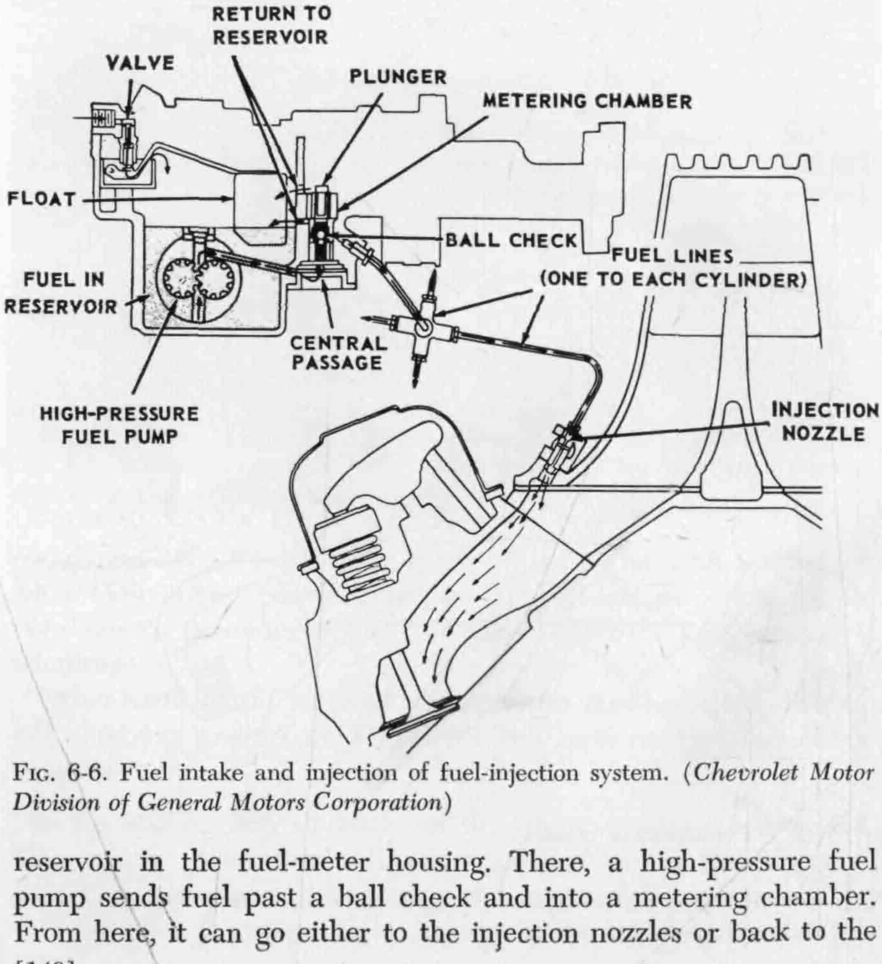


FIG. 6-6. Fuel intake and injection of fuel-injection system. (*Chevrolet Motor Division of General Motors Corporation*)

reservoir in the fuel-meter housing. There, a high-pressure fuel pump sends fuel past a ball check and into a metering chamber. From here, it can go either to the injection nozzles or back to the reservoir. The direction it flows depends upon the position of the plunger. Two positions of the plunger are shown in Fig. 6-7. To the left, the plunger is lowered so as to cause delivery of more fuel to the injection nozzles. This action results when the throttle is opened fairly wide and a high vacuum is being applied to the vacuum tube and to the vacuum diaphragm. The diaphragm lifts, raising the lever so that the lever pivots around the movable pivot, pushing down on the plunger. To the right in Fig. 6-7, the condition during low air flow is shown. Here, there is a low vacuum and the vacuum diaphragm has relaxed and permitted the lever to fall. Therefore, the plunger pushes up farther and less fuel flows to the nozzles.

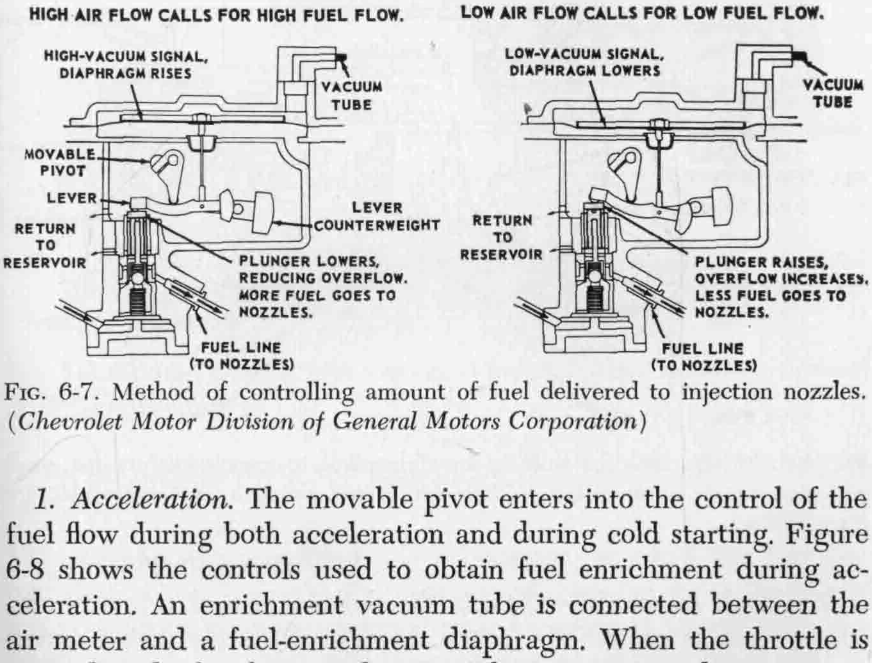


FIG. 6-7. Method of controlling amount of fuel delivered to injection nozzles. (*Chevrolet Motor Division of General Motors Corporation*)

1. Acceleration. The movable pivot enters into the control of the fuel flow during both acceleration and during cold starting. Figure 6-8 shows the controls used to obtain fuel enrichment during acceleration. An enrichment vacuum tube is connected between the air meter and a fuel-enrichment diaphragm. When the throttle is opened wide for fast acceleration, the vacuum in the air meter drops. This allows the fuel-enrichment diaphragm to relax so the spring pushes the diaphragm to the left (in Fig. 6-8). Through linkage, this pushes the movable pivot to the left and it assumes the position shown in Fig. 6-9. Now, with the pivot to the left, the plunger is forced down into the position in which it is shown to the left in Fig. 6-7. With more fuel flowing to the injection nozzles, a richer mixture and improved acceleration are attained.

2. *Cold starting.* An electrically heated choke enters into the action to provide control of fuel intake during cold starting (Fig. 6-9). Note that this illustration shows the electric choke cut into the fuel-enrichment vacuum line. On cold starts, vacuum in the choke housing from the fuel-enrichment vacuum line lifts a check ball and cuts off the vacuum to the enrichment diaphragm. Then the diaphragm relaxes and shifts the movable pivot to the left (in Fig. 6-9). In this position, the lever forces the plunger down so that more fuel

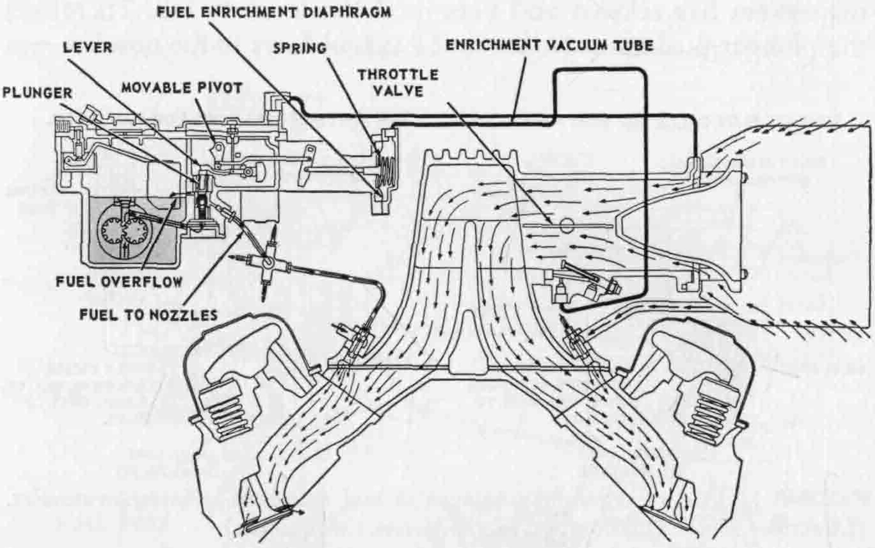


FIG. 6-8. Mechanisms for shifting movable pivot to enrich mixture for good performance on acceleration. (*Chevrolet Motor Division of General Motors Corporation*)

is delivered. As the thermostat in the choke is heated, it relaxes and allows vacuum to pull the piston downward. As the piston moves down, it pushes the check ball off its seat so that vacuum is permitted to pass through the choke and to actuate the fuel-enrichment diaphragm. This action causes the movable plunger to swing back into the warm-engine position so that the mixture is leaned out to that which is required for warm-engine operation.

The electric choke also controls a fast-idle cam that holds the throttle valve slightly opened for better idling when the engine is cold.

3. *Other features.* To provide adequate fuel quickly during engine cranking, a fast-start solenoid (see Fig. 6-4) is included in the fuel-meter assembly. This solenoid is actuated as the cranking motor operates (it is connected to the control circuit). The solenoid then operates linkage to the ball check below the plunger in the fuel meter to push the ball check off its seat so that the fuel pump can instantly deliver fuel to the injection nozzles. A fuel cut-off diaphragm (Fig. 6-4) comes into operation when coasting down hill or decelerating to shut off fuel flow. This diaphragm is connected by a tube to the air meter. When a high vacuum is produced in the air

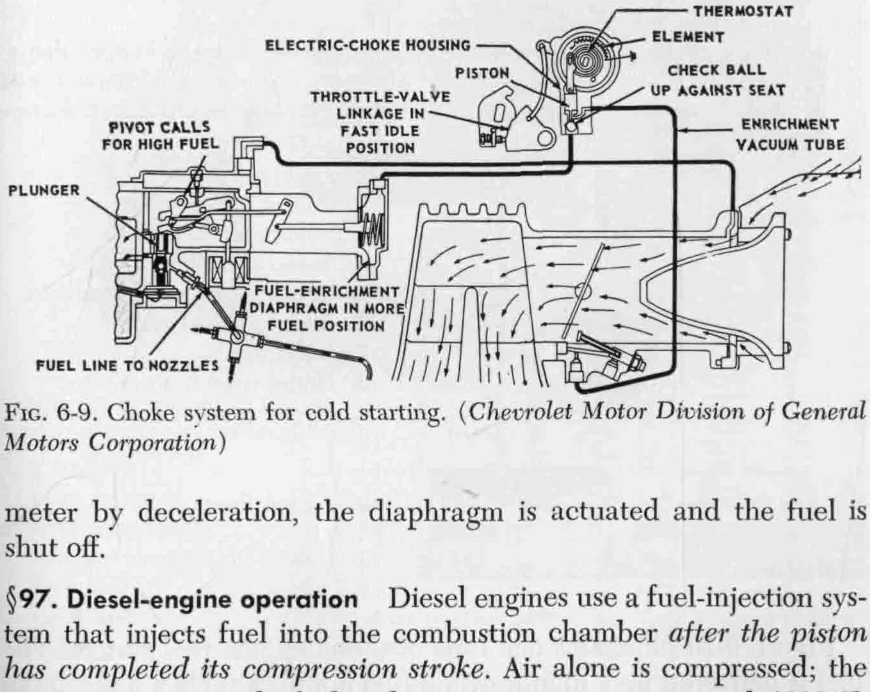


FIG. 6-9. Choke system for cold starting. (*Chevrolet Motor Division of General Motors Corporation*)

meter by deceleration, the diaphragm is actuated and the fuel is shut off.

§97. Diesel-engine operation Diesel engines use a fuel-injection system that injects fuel into the combustion chamber *after the piston has completed its compression stroke.* Air alone is compressed; the pressure goes up so high that the air temperature may reach 1000°F. Then, when the fuel is injected, it is ignited by the temperature of the air. Diesel engines are sometimes called *compression-ignition engines* for this reason. No ignition system, such as is used in automotive engines, is required.

§98. Diesel-engine fuel-injection system The diesel-engine fuel-injection system must have two special characteristics that the fuel-injection system already described does not require. First, the injection must be intermittent; a fuel nozzle must deliver fuel only at the time the piston is reaching top dead center on the compression stroke. Secondly, the fuel must be delivered at very high pressure since it is being injected into air that has been compressed to several hundred pounds per square inch of pressure. In addition to this, the amount of fuel delivered must vary with varying operating conditions so that more fuel is injected when more power is required.

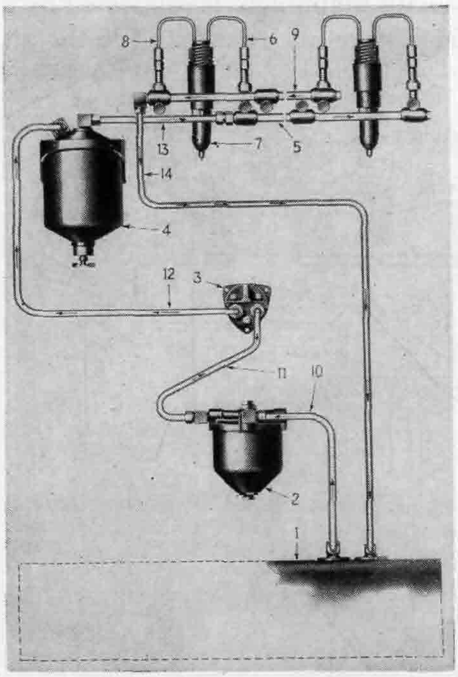


FIG. 6-10. General Motors diesel-engine fuel system. (*Detroit Diesel Engine Division of General Motors Corporation*)

1. Fuel tank
2. Primary filter
3. Fuel pump
4. Secondary filter
5. Lower (inlet) fuel manifold
6. Inlet tube to injector
7. Injector
8. Outlet tube from injector
9. Upper (outlet) fuel manifold
10.–14. } Fuel lines

Figure 6-10 illustrates one type of diesel-engine fuel system. The fuel is delivered by a high-pressure fuel pump through a filter to the fuel injectors. The fuel injectors are mounted above the engine cylinders as shown in Fig. 6-11 and are actuated by a camshaft, push rod, and rocker arm. When the cam lifts the push rod, the rocker arm forces a plunger in the injector to move down. The plunger has a helix cut in it as shown in Fig. 6-12. When the helix is not opposite either of the ports, it is effectively delivering fuel on its downward stroke, as shown. The effective stroke, and thus the amount of fuel delivered, can be varied by rotating the plunger.

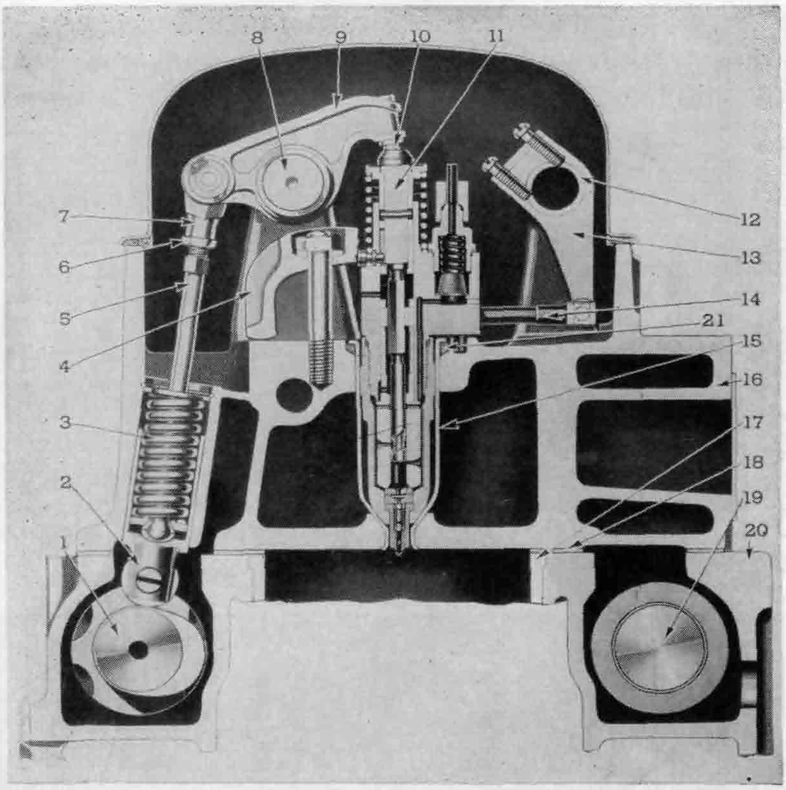


FIG. 6-11. Mounting of fuel injector above the engine cylinder. (*Detroit Diesel Engine Division of General Motors Corporation*)

1. Camshaft
2. Cam follower
3. Following spring
4. Injector clamp
5. Push rod
6. Lock nut
7. Clevis
8. Rocker-arm shaft
9. Injector rocker arm
10. Ball stud and seat
11. Injector assembly
12. Control tube
13. Rack-control lever
14. Injector control rack
15. Copper tube
16. Cylinder head
17. Cylinder liner
18. Cylinder-head gasket
19. Balancer shaft
20. Cylinder block
21. Copper-tube sealing ring

This effect is shown in Fig. 6-13. The plunger is rotated by means of a rack and gear that is linked to the accelerator pedal or control.

§99. Liquefied petroleum gas fuel systems Liquefied petroleum gas, or LPG, is a fuel that is liquid only under pressure.[1] When the pressure on LPG is reduced, it vaporizes. Thus, the first need in an

[1] Composition and characteristics of LPG are discussed in Chap. 7, "Automotive-engine Fuels."

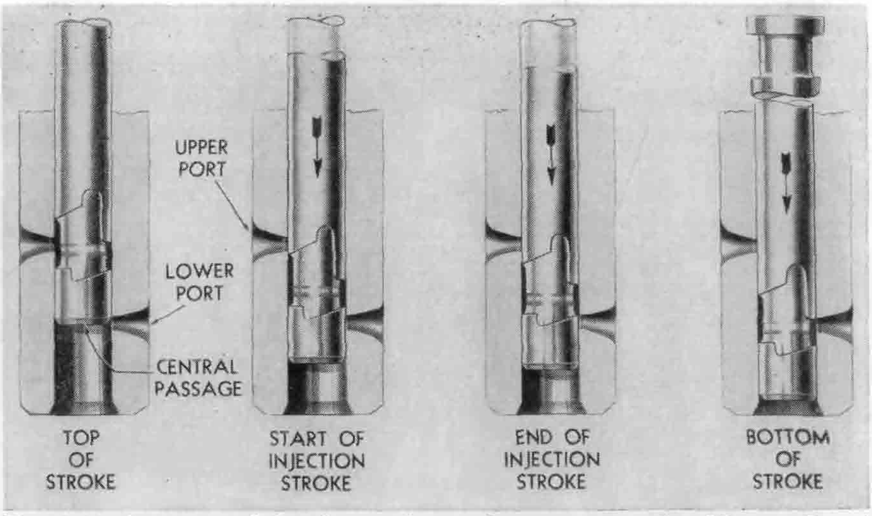


FIG. 6-12. Operation of the plunger during the injection stroke. (*Detroit Diesel Engine Division of General Motors Corporation*)

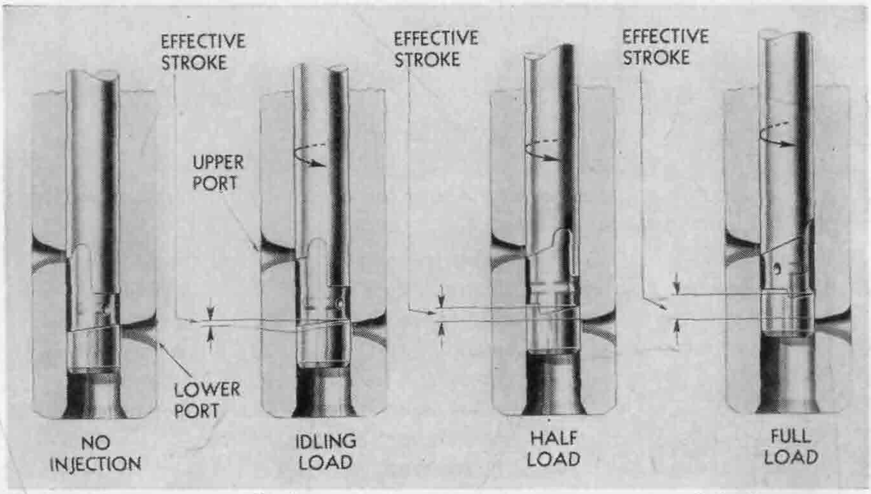


FIG. 6-13. Positions of plunger to secure various amounts of fuel injection. (*Detroit Diesel Engine Division of General Motors Corporation*)

LPG fuel system is a special pressure fuel tank that will keep the fuel under pressure until it is used. The pressure requirement also means that the storage tanks at the fueling points must be of special construction. In addition, LPG must be transported from the refineries or oil fields in special pressure-tank cars or trucks. For these reasons, engineers state that LPG is satisfactory as an automotive fuel only in fleet operations (trucks and busses), where there are enough vehicles to make it economically reasonable to invest in the special high-pressure storage equipment required.

Despite the greater cost of transporting and storing LPG (because of the special handling that pressure tanks require), its use is increasing in fleet operations. Some studies indicate that this increased cost is at least balanced by reduced operating and maintenance costs. Advantages claimed for LPG include:

1. Higher compression ratios can be used, with resulting increased engine power output.
2. No crankcase dilution due to failure of fuel to vaporize (LPG enters intake manifold completely vaporized).
3. No washing of oil from cylinder walls by unvaporized fuel and thus no wear from loss of lubrication.
4. Absence of deposits on valves and in combustion chamber.

A typical fuel system for LPG is shown in Fig. 6-14. Notice that it does not use a fuel pump. The pressure in the fuel tank is more

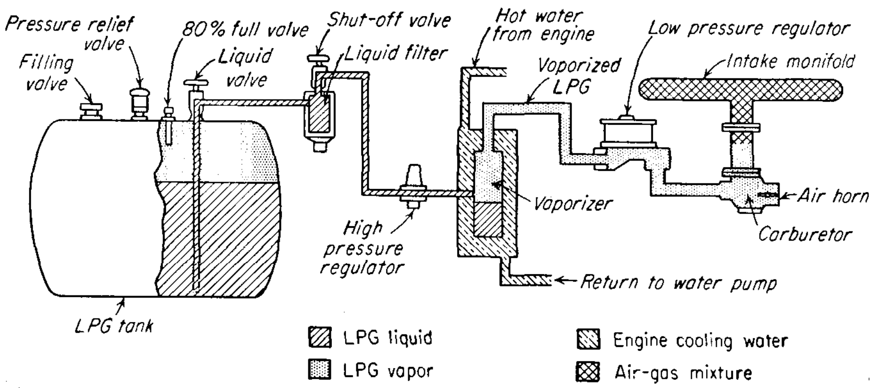


FIG. 6-14. Typical fuel system for LPG.

than sufficient to assure a flow of fuel to the carburetor. Actually, two pressure reducers, or regulators, are placed in the line so that the pressure is brought down to slightly below atmospheric before the fuel enters the carburetor.

1. The fuel tank is of heavy construction, capable of containing

pressures of at least 250 psi. Special filling and relief valves are required. The tank must not be filled more than 80 percent full, since there must be expansion room to take care of temperature variations. Many tanks are designed to use a special pressure nozzle that locks on the filling valve. The locking action opens the valve so that fuel can be pumped into the tank. At the same time, it closes a second valve to an inner expansion tank in the fuel tank. This inner expansion tank, which is 20 percent of the size of the fuel tank, provides the necessary expansion room for the fuel. Detaching the filling nozzle from the tank closes the filling valve and opens the valve to the expansion tank. Fuel can now expand into the expansion tank if temperature increases.

2. The shutoff valve provides a means of turning off the fuel for maintenance work. The filter removes from the liquid fuel any dirt that might have accumulated in it.

3. The liquid fuel is forced from the tank through the tube to the high-pressure regulator by the pressure in the tank. This pressure may run anywhere from 225 down to 20 psi. The high-pressure regulator reduces this pressure to somewhere between 5 and 15 psi (depending on the type of equipment). The LPG thus leaves the high-pressure regulator in a semiliquid condition, partly liquid, partly vapor. It then enters a vaporizer. The vaporizer consists essentially of an inner tank through which the fuel passes, and an outer tank through which hot water from the engine cooling system passes. The water adds heat to the fuel, assuring more complete vaporization. The vaporized LPG then passes through the low-pressure regulator and is reduced in pressure to a value slightly below atmospheric pressure. It is now ready to pass through the carburetor. Pressure must be reduced to slightly below atmospheric so that no fuel will flow until the engine is turning over and drawing air in through the carburetor. This action produces a vacuum in the carburetor venturi which causes fuel delivery in the carburetor.

4. The carburetor is essentially a mixing valve. It contains a throttle valve, an air horn, a venturi, and starting, idling, part-throttle, and full-throttle circuits. No provision for atomizing or vaporizing the fuel is needed, as with gasoline fuel systems, since the LPG enters the carburetor as a vapor. It passes through a gas orifice into the air stream in the air horn, and the mixture then

passes through the intake manifold to the engine cylinders. For part-throttle operation, many carburetors include a vacuum-operated economizer valve that reduces the size of the gas orifice when the throttle is partly opened and there is a vacuum in the intake manifold. When the throttle is opened wide and the vacuum is reduced, the economizer valve is released so that it opens and increases the size of the gas orifice. More fuel is thus delivered, and the mixture is enriched for full-throttle operation.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You may not run into fuel-injection or LPG fuel systems very often, but when you do, you will want to be able to deal intelligently with them. Thus, you will want to remember the important facts discussed in the chapter just completed. The following questions will give you a chance to review the material you have just covered on these fuel systems. Write down the answers in your notebook.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. In the diesel engine, fuel oil is injected into the cylinder toward the end of the *intake stroke* *compression stroke* *power stroke* *exhaust stroke*
2. In the diesel engine, fuel oil is injected into the cylinder at *low pressure* *high pressure* *60 psi*
3. In the General Motors diesel fuel system the fuel pump delivers the fuel oil through a filter to the *carburetor* *ignition distributor* *injectors*
4. In the General Motors diesel fuel system the injectors are operated through rocker arms from a *crankshaft* *camshaft* *gear shaft*
5. In the General Motors diesel system the effective pressure strokes of the plungers in the injectors are regulated by means of a *fuel pump* *control rack* *camshaft* *check valve*
6. The LPG fuel system does not use a *carburetor* *fuel tank* *fuel pump*
7. LPG must be stored as a *vapor* *liquid* *gas*

8. With LPG fuel, compression ratio of the engine can be *increased* *reduced* *eliminated*

Purpose and Operation of Components

In the following, you are asked to write down the purpose and operation of certain components of diesel and LPG fuel systems. Obviously, only one diesel fuel system has been covered in the chapter. There are many. It is suggested that you also attempt to learn about other diesel fuel systems as well as LPG fuel systems. You can write your answers to the questions below, as well as what you might learn about other diesel fuel systems and LPG fuel systems, in your notebook.

1. List some of the differences between diesel and gasoline engines.
2. Explain how an automotive fuel-injection system operates.
3. Explain how a typical diesel fuel-injection system operates.
4. Explain how the automotive fuel-injection system varies the amount of fuel injected to suit operating requirements of the engine.
5. What are the advantages claimed for LPG as a fuel?
6. What is the purpose of the pressure regulators in the LPG fuel system?
7. Explain how the LPG fuel system operates.

SUGGESTIONS FOR FURTHER STUDY

If you wish to learn more about diesel-engine fuel systems, you can refer to various books that have been written on diesel engines, as well as to the diesel-engine manufacturers' servicing and operating manuals. Late information on developments in LPG fuel systems can be found in automotive trade magazines and in publications of LPG producers and manufacturers of engines designed to use LPG. You will find it helpful for you to write down in your notebook any facts that you might learn about such fuel systems. Not only does this fix the information in your mind, but it also makes your notebook a valuable reference you can use to refresh your memory.

7: Automotive-engine fuels

THE PURPOSE of this chapter is to discuss the origin and characteristics of various automotive-engine fuels, including gasoline, LPG (liquefied petroleum gas), and diesel-engine fuel oil. In addition, the effect of the different characteristics of gasoline on engine operation are discussed.

§100. **Automotive-engine fuels** The American passenger-car engine uses gasoline as fuel. Other types of engines, for example, those used in tractors, trucks, and busses, may use kerosene, distillate alcohol, fuel oil, or LPG. Since this book deals primarily with gasoline-engine fuel systems, only gasoline will be discussed in detail. However, diesel fuel oil and LPG are covered in special sections at the end of this chapter. Diesel-engine and LPG fuel systems are described in Chap. 6, "Diesel and LPG Fuel Systems."

§101. **Gasoline** Gasoline appears to be a simple compound when you first examine it. It is a clear or colored liquid that evaporates quickly from a flat pan and burns violently in the open air. Gasoline is not, however, a simple compound. It is a complex mixture of several compounds. It is a blend of a number of different basic fuels, each of which contributes its own characteristics to the mixture.

Gasoline is a hydrocarbon, since it is made up of hydrogen and carbon compounds. We have already noted that, when gasoline burns, the hydrogen and carbon atoms separate from each other and combine with oxygen atoms (see §27). It is this combustion process that produces the high pressure in the cylinder that forces the piston down so that the engine produces power.

§102. **Origin of gasoline** Gasoline, diesel fuel oil, LPG, and many other compounds are obtained from petroleum, or crude oil. No one knows exactly how petroleum originated. It is found in "pools" under the ground, and there is evidence that it was formed over a space of many millions of years from animal or vegetable sources. The petroleum usually is under considerable pressure; when a well is drilled down to a pool or reservoir, the petroleum gushes up out of the earth.

Petroleum is a very intricate mixture of many compounds. The oil refinery separates the petroleum into various substances. It alters many of the original compounds and forms new compounds in the refining process. From the refinery come many types and grades of lubricating oil, fuel oil of various types for diesel engine, heating, and so forth, gasoline of many grades and types, kerosene, LPG, and so on.

As mentioned above, gasoline is blended from a number of different basic hydrocarbons, each with its own set of characteristics. By blending various basic fuels, a gasoline is obtained that will provide satisfactory engine operation under the many different operating conditions that the engine will meet. Factors that must be considered in blending gasoline include volatility, antiknock value, and freedom from harmful chemicals and gum. These factors are discussed in detail in following sections.

§103. Volatility Volatility refers to the ease with which gasoline and other liquids vaporize. The volatility of a simple compound like water or alcohol is determined by increasing its temperature until it boils, or vaporizes. A liquid that vaporizes at a relatively low temperature has a high volatility; it is highly volatile. If its boiling point is high, it has a low volatility. A certain heavy oil, for example, has a low volatility since it will not boil until it reaches a temperature of over 600°F. Water is relatively volatile since it boils at 212°F (at atmospheric pressure). Gasoline is still more volatile.

It is also true that a highly volatile substance will evaporate much faster at a low temperature than a substance with a low volatility. Thus, at room temperature, alcohol and gasoline will evaporate more rapidly than water.

Gasoline is blended from different hydrocarbon compounds that have different volatilities or boiling points. Some compounds of gasoline will therefore evaporate more readily at low temperatures than others. This combination assures satisfactory operation under the various operating conditions the engine meets, as follows.

1. *Easy starting.* For easy starting with a cold engine, gasoline must be highly volatile so that it will vaporize readily as it passes through the carburetor even when air and fuel temperatures are low. Thus, a certain percentage of the gasoline must be volatile enough to permit easy starting. In winter the percentage of high-volatility gasoline is increased for good cold-weather starting. Also, the percentage of high-volatility gasoline is varied for the different parts of the country; the percentage is higher in the colder Northern states.

2. *Freedom from vapor lock.* If the gasoline is too volatile, heat from the engine will cause it to vaporize in the fuel lines and fuel pump. This action results in gas pockets, or *vapor locks*, that prevent normal fuel-pump action. When gas pockets exist, the increasing and decreasing pressure in the fuel line (due to fuel-pump action) simply causes the pockets to contract and expand. Thus, little or no fuel is pumped from the fuel tank to the carburetor. The engine then loses power or completely stalls from fuel starvation. To prevent vapor locks, the percentage of highly volatile gasoline must be kept relatively low. Thus, it can be seen that the requirements for easy starting and requirements for freedom from vapor lock are in opposition. That is, there must be enough high-volatility gasoline for easy starting, but not so much as to cause vapor lock.

3. *Quick warm-up.* The speed with which the engine will warm up depends in part on the percentage of gasoline that will vaporize immediately after the engine is started (and thus contribute to engine operation). Volatility for this purpose does not have to be quite so high as for easy starting. This is because immediately after starting, the air speed through the carburetor is greater, and turbulence in the manifold and cylinder during intake and compression helps to vaporize the gasoline.

4. *Smooth acceleration.* When the throttle is opened for acceleration, there is a sudden increase of air rushing through the carburetor into the engine cylinder. At the same time, the accelerator pump delivers an extra amount of gasoline. If the gasoline does not vaporize quickly during this interval, a large mass of air will reach the cylinders without carrying its proper proportion of gasoline vapor. The mixture entering the cylinders will be too lean for good combustion, and the engine will hesitate or stutter. Immediately

afterward, as the gasoline metered out by the accelerator pump begins to vaporize, the mixture reaching the cylinders will become too rich. This again produces poor combustion and a logy engine. The result is uneven and inferior acceleration. A sufficient percentage of the gasoline must be volatile enough to prevent this condition. But on the other hand, if too large a percentage of the gasoline is highly volatile, there will be an overrich mixture on acceleration. This would cause the engine to "roll" or "load up," causing poor acceleration.

5. *Good economy.* For good fuel economy, or maximum miles per gallon, the fuel must have a high heat, or energy, content and relatively low volatility. High over-all volatility tends to reduce economy, since the mixture may become overrich under many conditions of operation. On the other hand, the lower-volatility fuels tend to burn more efficiently, providing better fuel economy. But the lower-volatility gasolines increase starting difficulty, reduce speed of warm-up, and do not give good acceleration. Thus, only a limited percentage of the gasoline can be of low volatility.

6. *Freedom from crankcase dilution.* When gasoline is not sufficiently volatile, some of it will enter the cylinder in liquid form, as tiny unevaporated droplets. These droplets spray on the cylinder walls, washing off the film of lubricating oil. Removing the lubricating-oil film in this manner increases the rate at which the cylinder wall, piston rings, and piston will wear. Furthermore, the liquid gasoline passes the piston rings and enters the oil pan, or crankcase. The lubricating oil is thus diluted by the gasoline, and it loses some of its lubricating ability. This means that all moving engine parts will wear more rapidly. After the engine has operated for a while and has thoroughly warmed up, this liquid gasoline in the crankcase begins to vaporize and is removed by the crankcase ventilating system (described in §223). To avoid damage to the engine before it warms up, the gasoline must be sufficiently volatile to avoid crankcase dilution.

7. *The volatility blend.* It is obvious from the above discussion that no one volatility would satisfy all engine operating requirements. On the one hand, the fuel must be of high volatility for easy starting and acceleration. But it must also be of low volatility to give good fuel economy and combat vapor lock. Thus, gasoline must be blended from various amounts of fuels having different

volatilities. Such a gasoline then satisfies the various operating requirements.

§104. Antiknock value During normal combustion in the engine cylinder, an even increase of pressure occurs. But if the fuel burns too rapidly, or "explodes," there is a sudden and sharp pressure increase. This sudden pressure increase produces a rapping or knocking noise that sounds almost as though the piston head had been struck with a hard hammer blow. Actually, the sudden pressure increase does impose a sudden heavy load on the piston that is almost like a hammer blow. This can be very damaging to the engine, wearing moving parts rapidly and perhaps even causing parts to break. Furthermore, the energy in the gasoline is wasted since the sudden pressure increase does not contribute much toward the production of power.

It has been found that some types of gasoline burn very rapidly in engine cylinders and thus knock very badly. Other types of fuel burn more slowly and thus do not knock. Also, certain chemicals have been found which, when added to the gasoline, will slow down the rate of burning so that knocking is eliminated. Gasoline is rated according to how easily it will knock, that is, by its antiknock value. The actual rating is by *octane number*. This term, and the theory of knocking, are discussed in following sections.

§105. Compression ratio Before we discuss the antiknock value of gasoline further, let us talk about engine compression ratio since this is very directly connected to knocking. On the compression stroke, the piston moves up and compresses the air-fuel mixture in the cylinder. The amount that the mixture is compressed is determined by the engine design; that is, by one specific characteristic of the engine called the *compression ratio*. The compression ratio is the ratio of the volume in the cylinder with the piston at BDC (bottom dead center) to the volume with the piston at TDC (top dead center). This is shown in Fig. 7-1. For example, let us assume that the volume in the cylinder with the piston at BDC (*A* in Fig. 7-1) is 40 cubic inches and the volume at TDC is 5 cubic inches. In other words, as the piston moves up from BDC to TDC, it compresses the air-fuel mixture from 40 cubic inches to 5 cubic inches. The proportion, or ratio, of compression is 40 to 5, or 8 to 1 (written 8:1). In other words, the compression ratio is 8:1.

The higher the compression ratio, the more the air-fuel mixture is "squeezed" on the compression stroke. Thus, there is a higher initial pressure at the beginning of the power stroke. This means, in turn, that there is more pressure on the piston as combustion begins, which brings us to the basic advantage of higher compression ratios. With more pressure on the piston during the combustion stroke, more power will result. Therefore, increasing the compression ratio increases engine output. That is the reason engine designers and manufacturers are producing engines of higher and higher compression ratios. By redesigning the engine to step up compression ratio, they get an engine with a higher horsepower output without a comparable increase in size. In fact, modern high-compression engines weigh much less and are much more powerful than earlier engines.

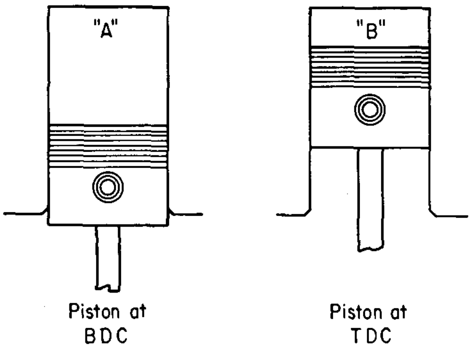


FIG. 7-1. Compression ratio is volume in cylinder with piston at BDC divided by volume with piston at TDC, or *A* divided by *B*.

The increase of compression ratio has brought about certain difficulties, however, since a high-compression engine has a greater tendency to knock. Thus, it has been necessary to find fuels that resist knocking for these higher-compression engines. A great deal of research, both in the laboratory and on testing grounds, has been done to find these antiknock fuels.

§106. Heat of compression To understand why knocking occurs, it is first necessary to understand what happens to any gas when it is compressed. We have already noted that in the diesel engine, when the air is compressed to one-fifteenth of its original volume (compression ratio 15:1), the air temperature increases to about 1000°F (§93). The more a gas is compressed, the higher its temperature will go. This temperature rise is called *heat of compression.*

§107. Cause of knocking During normal burning of fuel in the combustion chamber, the spark at the spark plug starts the burning process. A wall of flame spreads out in all directions from the spark, almost like a rubber balloon being blown up. The wall of flame travels rapidly outward through the compressed mixture in the combustion chamber until all the charge is burned. The speed with which the flame spreads is called the *rate of flame propagation.* The movement of the flame wall through the combustion chamber during normal combustion is shown in the row of pictures to the left in Fig. 7-2. During combustion, the pressure in the combustion chamber increases to several hundred pounds per square inch (psi). It may exceed 700 psi in the modern high-compression engine.

If the flame travels too rapidly through the mixture (rate of flame propagation is too high), the pressure will increase too rapidly and will go too high. The effect will be as shown to the right in Fig. 7-2. The rapid increase of pressure, and excessive pressure, will cause the last part of the charge to detonate, or explode, with hammerlike suddenness. The effect is almost the same as if you had suddenly struck the piston head with a heavy hammer blow. In fact, it *sounds* as though this had happened. The sudden explosion of the last part of the charge hammers on the piston head, and imposes a heavy shock load on the piston, connecting rod, crankshaft, and bearings. With very severe knocking, engine parts will actually be broken.

Let's take a closer look at knocking. We have mentioned that knocking results from an excessively rapid increase in pressure. This rapid pressure increase highly compresses the remaining unburned charge. Heat of compression (§106) then raises the temperature of the unburned charge. Detonation, or knocking, occurs when the temperature has gone up so high that the remaining unburned charge explodes. To sum up, the process is about as follows. The spark occurs and combustion starts. The charge starts burning too rapidly (rate of flame propagation too high). Pressures go up excessively, developing excessive heat of compression in the unburned charge. The heat of compression then sets off the remainder of the charge.

As compression ratios of engines have gone up, so also has the tendency of the engines to knock. With higher compression ratios,

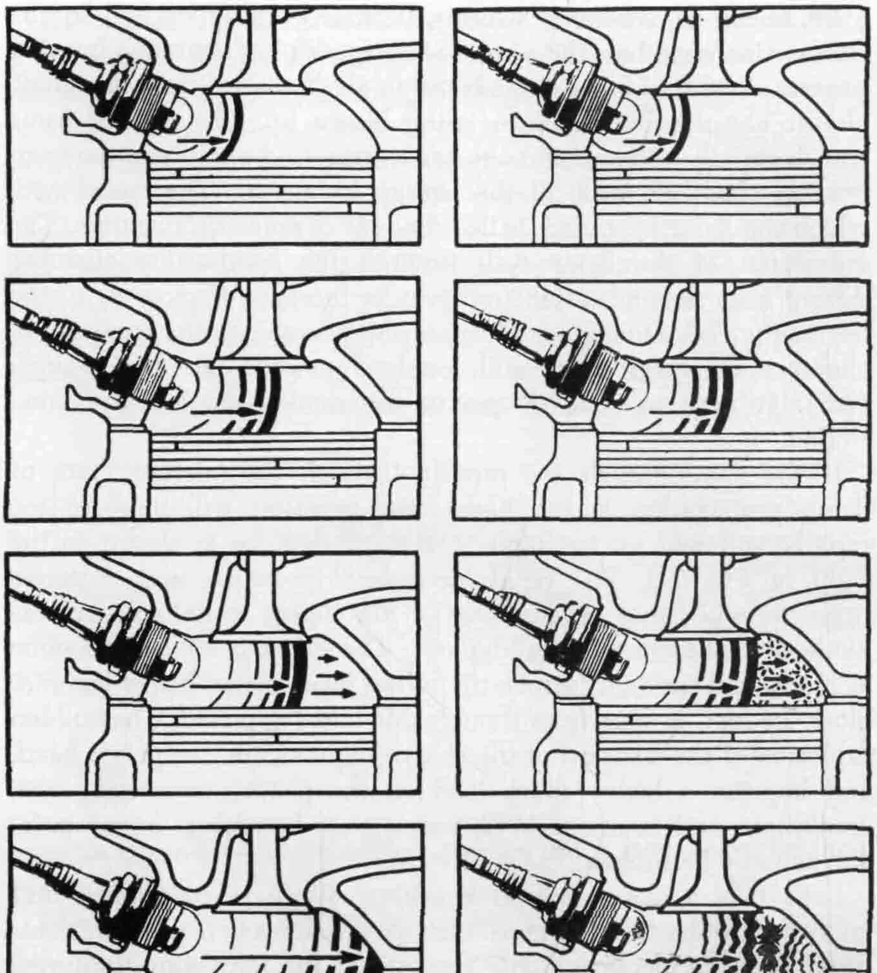


FIG. 7-2. Normal combustion without knocking is shown in the vertical row to the left. The fuel charge burns smoothly from beginning to end, providing an even, powerful thrust to the piston. Knocking is shown in the vertical row to the right. The last part of the fuel explodes, or burns almost instantaneously, to produce detonation, or knocking. *(General Motors Corporation)*

the mixture, at TDC, is more highly compressed and *is at a higher initial temperature.* With higher initial pressure and temperature, the temperature at which detonation occurs is sooner reached. Thus, high-compression engines have a greater tendency to knock. However, special fuels have been developed for use in such engines as explained below. These special fuels have a greater resistance to being set off suddenly by heat of compression. They are less apt to explode suddenly, and they depend for their ignition upon the wall of flame traveling through the air-fuel mixture.

§108. Measuring antiknock values of fuels Several methods of testing fuels to determine their tendency to knock in engines have been developed. Some fuels knock rather easily; others have a high resistance to knock (that is, have a high antiknock rating). Actual rating of a fuel for its antiknock value is made in terms of *octane* rating. A high-octane gasoline is highly resistant to knock, a low-octane gasoline knocks rather easily. There is a fuel called *iso-octane* that is extremely resistant to knocking; it is given an octane rating of 100. Another fuel, called *heptane,* knocks very easily; it is given an octane rating of zero. A mixture of half iso-octane and half heptane (by volume) would have a 50-octane rating. A mixture of 75 percent iso-octane and 25 percent heptane would have a rating of 75 octane.

Actually, iso-octane and heptane are reference fuels, used only to rate unknown fuels. One rating procedure makes use of a test engine (Fig. 7-3) so built that its compression ratio can be varied. A fuel to be rated is used to run the engine, and the compression ratio is increased until a certain intensity of knocking is obtained. Then, reference fuels of varying proportions of iso-octane and heptane are used to run the engine. The octane rating of the reference fuel is decreased (by using smaller percentages of iso-octane) until the same intensity of knocking results as was obtained with the fuel to be rated. Then, the fuel being rated is given the same octane number as the reference fuel since both produce the same amount of knocking. If the reference fuel has 68 percent iso-octane, for example, then it and the fuel being tested are considered to have the same 68-octane rating.

1. *Laboratory-test method.* The laboratory-test method of measuring octane rating of a fuel has already been described. Essentially,

the test engine is operated at a certain speed, with a certain ignition spark advance, and the compression ratio is varied until the test fuel causes knocking. Note that all conditions except compression ratio are kept constant through the test. This differs from actual over-the-road operation, where the compression ratio stays the

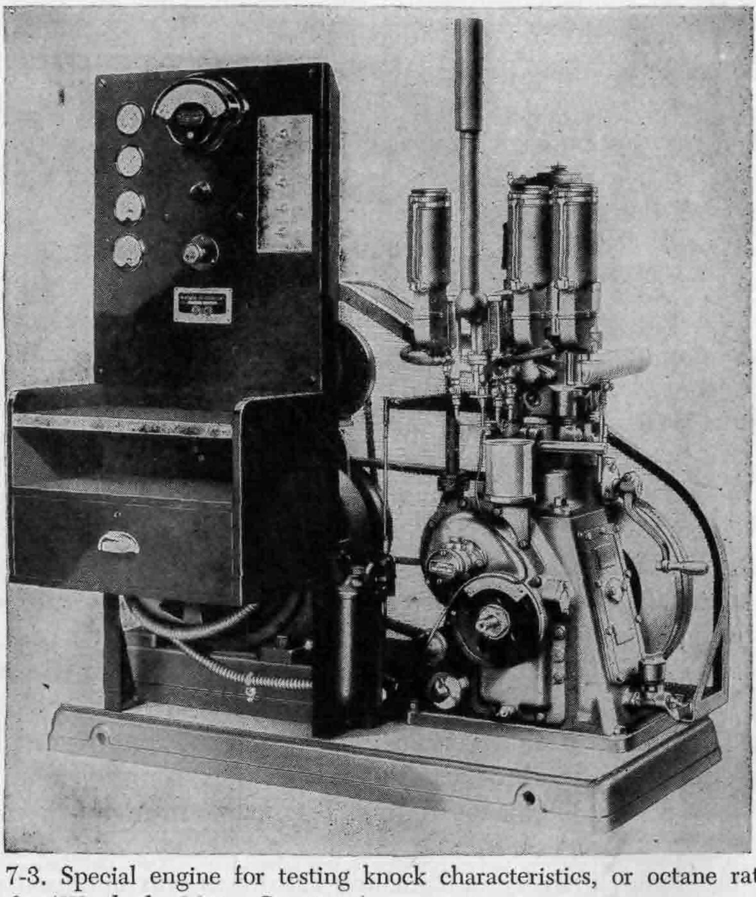


FIG. 7-3. Special engine for testing knock characteristics, or octane ratings, of fuels. (*Waukesha Motor Company*)

same (it's built into the engine) but most other conditions change (including speed, spark advance, temperature, carburetion, fuel distribution to cylinders, and so forth). This difference between laboratory-test procedure and actual operating conditions has been apparent in the highway performance of laboratory-rated fuels. A fuel that knocks in one engine may not knock in another. A fuel that knocks at low speed may not knock at high speed. Another fuel may knock at high speed but not at low speed. However, despite the fact that the laboratory rating cannot pin-point octane rating of a fuel for all kinds of performance, it is still of value since it does give *comparative* ratings between different fuels.

2. *Road-test methods.* In order to determine more accurately how a fuel will act in normal highway operation, a number of road octane-rating tests have been developed. One of these, the Cooperative Fuel Research Uniontown road test (called the CFR Uniontown road test), rates fuels for knock intensity at wide-open throttle

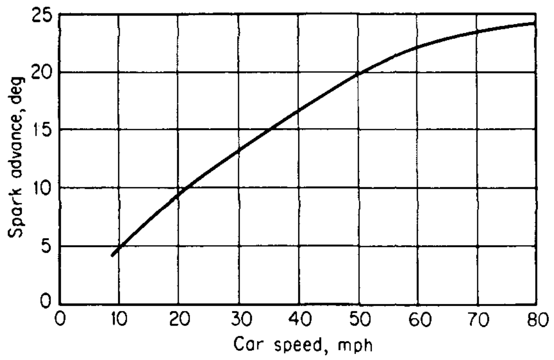


FIG. 7-4. Borderline knock curve. The fuel being tested will knock if the ignition spark is advanced to any value above the curve at any speed.

at various speeds. Octane is assigned by comparing knocking of the fuel being tested to reference fuels (iso-octane and heptane mixtures) of known octane values.

Another method, the *borderline knock test,* rates the fuel at various speeds and is considered to give much more information on fuel performance. This test is made by running the car at various speeds and then determining the amount of ignition spark advance the fuel can tolerate at each speed without knocking. If the spark is advanced too much at any speed, knocking will occur. Thus, the test results give us a curve that shows, at every speed, the knock characteristics of the fuel being tested (Fig. 7-4). Note, in Fig. 7-4, that the fuel tested permits an increasing spark advance with increasing speed. Any advance above the curved line causes knock.

To show how different fuels might act in the borderline knock test, see Fig. 7-5. This shows the curves of two fuels, *A* and *B*. Curve *C* is the amount of spark advance the distributor provides on the engine used in the test. If, at any particular speed, the distributor advances the spark more than the fuel can tolerate, the fuel will knock. Thus, at low speed, fuel *A* will knock since the spark advance is more than the fuel can tolerate (that is, curve *C* is above curve *A* at low speed). On the other hand, fuel *A* will not knock at high speed since the spark advance is not up to the amount the fuel can tolerate at high speed. But fuel *B* gives a different story. It will not knock at low speed, but does knock at

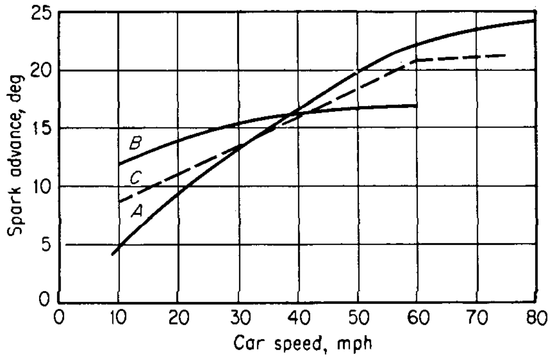


Fig. 7-5. Comparison of borderline knock curves of two fuels, *A* and *B*. Curve *C* is the spark advance actually provided by the ignition distributor on the engine.

high speed. These curves, which apply only to fuels *A* and *B* emphasize the fact that different fuels act differently at different speeds and in different engines.

CHECK YOUR PROGRESS

Progress Quiz 5

Here is your progress quiz for the first half of the chapter. You will note that these checkups are included only in the longer chapters. They are designed to give you a breathing spell and allow you to stop to find out how well you are learning the essential details of the fuel system that you are studying. Whenever you are reading a book, it is always desirable to stop every few pages to sum up what you have been reading. In this way, you review the material, and it will be much easier to remember. The progress quizzes throughout the book, as well as the chapter checkups, give you the chance to make these periodic reviews.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The most used internal-combustion-engine fuels are *coal, coke, and oil* *gasoline, LPG, and oil* *alcohol, gasoline, and LPG*
2. The ease with which a liquid vaporizes is called its *vaporability* *volatility* *octane rating*
3. Vapor lock is most apt to occur in the *fuel lines or pump* *fuel pump or tank* *carburetor or tank* *tank or gauge line*
4. The possibility of vapor lock increases as *volatility decreases* *volatility increases* *octane rating increases*
5. For good fuel economy the gasoline must have a high energy content and relatively *low volatility* *high volatility* *high octane*
6. To avoid crankcase dilution and washing of the cylinder walls, the gasoline must have a relatively *low volatility* *high volatility* *high octane*
7. The antiknock value of gasoline is referred to in terms of *octane number* *volatility number* *compression number* *heptane number*
8. The temperature rise of a gas that is compressed is called *compression ratio* *octane number* *volatility rating* *heat of compression*
9. The speed with which the flame travels through the burning air-fuel mixture in the combustion chamber is called the *rate of fuel burning* *rate of flame propagation* *rate of compression* *rate of ignition*
10. A fuel that knocks at low speed *has a high-octane rating* *may not knock at high speed* *will always knock at high speed*

§109. Detonation versus preignition Thus far, we have been discussing the type of knocking that results from detonation, or sudden explosion, of the last part of the fuel charge in the cylinder. This type of knocking is usually regular in character and is most noticeable when the engine is accelerated or is under heavy load, as when climbing a hill. Under these conditions, the accelerator is fully open, or nearly so, and the engine is taking in a full air-fuel charge on every intake stroke. This means that the compression pressures are at the maximum; detonation pressures are more apt to be reached after the mixture is ignited.

There is another type of knocking, which has a different cause—preignition. Preignition occurs whenever the air-fuel mixture is ignited by any means other than the spark at the spark plug. For example, there might be a build-up of carbon on the piston head. High spots of the carbon build-up might become hot enough to glow; these glowing high spots of carbon could ignite the mixture before the spark occurs. A hot exhaust valve or spark plug might do the same thing. Even loose particles of carbon floating in the combustion chamber could cause preignition. The knocking that results from preignition is irregular; it is often called *wild* knocking since it can occur almost any time after the intake valve opens to start admitting the air-fuel charge.

§110. Chemical control of knocking In the research work on the problem of finding higher-octane gasolines for the higher-compression engines, many chemical compounds were tested. When added to the gasoline, some of these compounds had an inhibiting effect on the fuel that prevented the last part from detonating. One theory regarding this effect is that the compound retards the rate of flame propagation through the compressed mixture; this prevents the rapid pressure rise and "squeezing" of the last part of the compressed charge that would cause it to explode. One of the compounds that was most successful in preventing knocking was tetraethyllead, commonly called *ethyl* or *tel.* A small amount added to gasoline raises the octane, or antiknock, rating of the gasoline. Within limits, the more added, the higher the octane rating.

§111. Factors affecting knocking In any particular engine a great many mechanical factors will affect the tendency to knock. Many tests have been made to establish the relationship between temperature, humidity, ignition spark advance, engine deposits, and so forth, and knock tendency. Test results are usually given in terms of octane-number increase necessary to eliminate knocking. For example, it is known that a hot engine will knock more easily than a cold engine. To get exact data on this, an engine is operated cold on the lowest-octane fuel it can use without knocking. Then it is operated hot on the lowest-octane fuel it can use without knocking. The difference in octane numbers is an indication of the increased octane requirements as the engine warms up. For example, one test showed that increasing the temperature of the cooling water in an engine from 100 to 190°F increased the octane requirements by 22 numbers (from 50 to 72, for instance). Other tests have shown the following.

1. A 20° rise in air temperature increases octane requirements by about three numbers.
2. An increase in humidity from 40 to 50 percent at 85°F reduces octane requirements by one number. This is laboratory proof of the common belief that the engine does run better and more quietly in damp weather.
3. Engine deposits increase octane requirements since they increase the compression ratio (part of the compression space is taken up by deposits). One series of tests showed that after about 10,000 miles of operation, engine deposits increased octane requirements by nine numbers.
4. Advancing the spark or leaning the mixture increases the octane requirements.

All these factors point up the need for good maintenance of the modern high-compression engine. Accumulation of scale in the cooling system, reducing cooling efficiency; deposits in the combustion chambers; clogged fuel lines or nozzles in the carburetor, which lean out the mixture; improper ignition timing—all these increase the tendency to knock and require an increase of octane number to prevent knocking.

§112. Chemical versus mechanical octane Octane number can be increased by adding a chemical such as tel (tetraethyllead). Octane requirements of the engine can be changed by changes in engine design as well as by changes in operating conditions. The previous section discussed several operating conditions that increased or lowered octane requirements. We have also mentioned the fact that increasing compression ratio increases octane needs. Mechanical octane (or octane need) of an engine can also be altered by changes in piston and combustion-chamber shape. Figure 7-6 shows a series of combustion-chamber shapes which were tested during design work on the Buick V-8 engine. All these were run under identical conditions of speed, power output, compression ratio, and so forth. The only variation was in the octane number of the fuels used. Fuels were selected for each design as required to avoid knock. It was found that design *A* required 96-octane fuel to run without knocking while design *J* required only 88-octane fuel. Thus, there is a difference of 8 mechanical octanes between design *A* and design *J*. Several reasons for the lower mechanical octane of design *J* have been stated. For one thing, the flame-travel

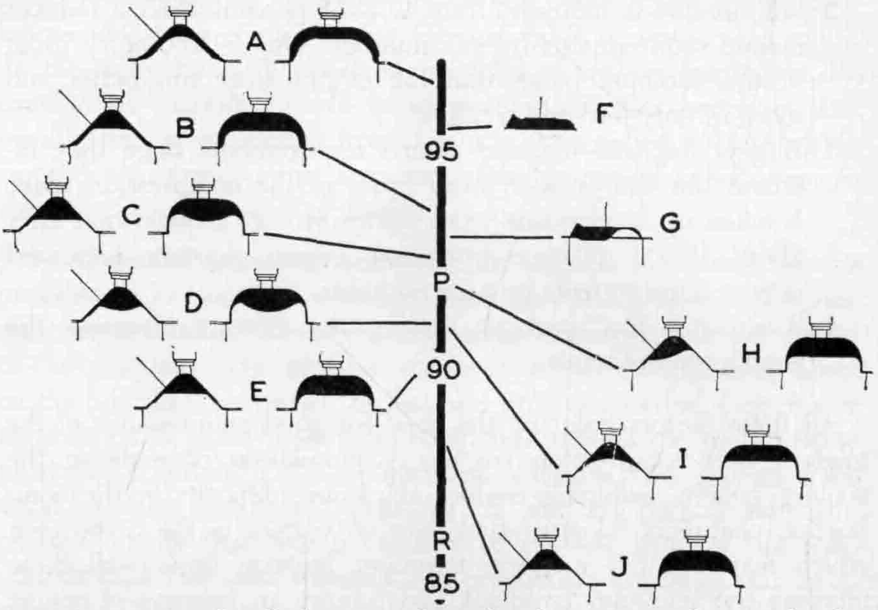


FIG. 7-6. Octane "tree" showing relationship between combustion-chamber design and octane requirements. Two views of the combustion chamber are shown for each design (end and side) except for designs *F* and *G*. (*Buick Motor Division of General Motors Corporation*)

distance is short so that no distant "pocket" of charge remains to detonate after most of the fuel has burned. Also, turbulence of the mixture is high so that no static "pockets" of charge result as the compression stroke is completed.

§113. Octane requirements Octane requirements of an engine are determined basically by the engine design. However, these requirements will change with weather and driving conditions as well as with the mechanical condition of the engine. We have noted in §111 how changing temperature and humidity change the octane needs of the engine. It is also true that engine deposits, reduced cooling-system efficiency, and carburetor or ignition troubles will change octane requirements.

In addition to all these, the manner in which the driver operates the car has a marked effect on octane needs. If the driver is moderate and does not demand quick getaway and high speed, he will seldom open the throttle wide and his engine will therefore be much less apt to knock (and thus have lower-octane requirements). On the other hand, this type of operation tends to hasten engine deposits; this, of course, means an ultimate increase in octane needs. The driver who demands full engine power for rapid acceleration and high-speed operation will need a higher-octane fuel, even with a new engine.

It is interesting to note that automatic transmissions make a difference in octane needs. With an automatic transmission, the engine is usually operated at part to full throttle at a fairly high engine rpm (revolutions per minute). There is very little low-engine-speed, full-throttle operation such as you find with manual transmissions. The difference here is, of course, in the manner of coupling. The manual transmission uses a mechanical clutch that connects the engine and rear wheels rigidly. But the automatic transmission uses a fluid coupling or torque converter which allows slippage; on acceleration the engine may turn at high speed while the car is moving at low speed. Thus, with an automatic transmission, you don't need to worry about knocking during low-engine-speed, wide-open-throttle operation, because you don't have this type of operation. Consequently, a fuel such as is indicated by curve *A* in Fig. 7-5 would be more suitable than fuel *B*. Fuel *A* will tend to knock at low engine speed but not at high engine speed (with spark advance indicated by curve *C* in Fig. 7-5). Fuel *B* will not knock at low engine speeds but tends to knock at high engine speeds. Section 108 discusses variations in octane of different fuels.

§114. Harmful chemicals and gum in gasoline In addition to having the proper volatility and antiknock properties, gasoline must have minimum amounts of harmful chemicals and gum-forming substances. For instance, sulfur compounds are often found in gasoline and, when present in excessive quantities, will cause damage to engine parts. As the gasoline burns in the engine, the sulfur present tends to form sulfur acids. Sulfur acids attack metal parts and bearings and corrode them. Gum-forming substances may be dissolved in gasoline; as the gasoline evaporates, the gum solidifies in gasoline passages in the carburetor and intake manifold and on valves, pistons, and piston rings. Such gum formation can cause serious difficulty since it hinders the action of the fuel system and moving engine parts. Insufficient gasoline will be delivered, intake valves may hang open, and piston rings may stick. Gasoline manufacturers maintain rigid controls in their refineries so as to hold sulfur compounds and gum-forming substances to a minimum in their gasolines.

§115. Chemistry of combustion We have already discussed the combustion process in the engine (§27) and have noted that gasoline *is a hydrocarbon (composed of hydrogen-carbon compounds). The hydrogen and carbon atoms unite with oxygen atoms during combustion to form water* (H_2O) and carbon dioxide (CO_2) *when enough oxygen is present.* However, in the gasoline engine sufficient amounts of oxygen may not be available, and the oxygen present may not "get to" the carbon. As a result, the carbon does not attain complete combustion. Some atoms of carbon are able to unite with only one atom of oxygen (instead of two). This produces carbon monoxide (CO). Carbon dioxide is a relatively inert and harmless gas, but carbon monoxide is dangerously poisonous. It has no color, is tasteless, and has practically no odor. A ratio of 15 parts of carbon monoxide to 10,000 parts of air is dangerous to breathe. Higher concentrations may cause quick paralysis and death. Consequently, an engine should never be operated in a closed space, such as a garage, without some means of exhausting the gas into the outside air. Remember this fact: Enough carbon monoxide can be produced in 3 minutes by an automobile engine running in a closed 10- by 10- by 20-foot garage to cause paralysis and death! *Never operate an automobile engine with the garage doors closed!*

§116. Diesel-engine fuels You will recall that the diesel engine compresses air alone on the compression stroke and then injects fuel oil at the start of the power stroke (§§93 to 98). The oil is ignited by the heat of the compressed air so that combustion and the power stroke follow. Diesel fuel oil is a relatively light oil, produced by a refining process from crude oil, or petroleum. A good diesel fuel oil must have certain characteristics, including proper viscosity, cetane number, and freedom from dirt or harmful chemicals. These are discussed below.

§117. Viscosity "Viscosity" is a term that refers to the tendency of a liquid to resist flowing. Water has a very low viscosity; it flows very easily. A light oil is more viscous than water, but it still has a rather low viscosity since it flows quite easily. But a heavy oil flows slowly; it has a high viscosity. The fuel oil used in a diesel engine must have a relatively low viscosity so that it will flow easily through the pumping and injection system that supplies the fuel to the engine cylinders. It must also be of relatively low viscosity so that it will spray, or atomize, easily as it is injected into the cylinder. If it is too viscous, it will not break up into fine enough particles; this means that it will not burn rapidly enough, and engine performance will be poor. On the other hand, it must be of sufficiently high viscosity to lubricate the moving parts in the fuel system satisfactorily and to help seal the moving parts and prevent leakage.

§118. Cetane number The cetane number of diesel fuel might be compared, in a way, to the octane number of gasoline. "Cetane number" refers to the ignition quality, or ease of ignition, of the fuel. The lower the cetane number, the higher the temperature required to ignite the fuel. Or, to say it the other way around, the higher the cetane number, the lower the auto-ignition point (or temperature required to ignite the fuel). And the higher the cetane number of a diesel fuel, the less the tendency for the fuel to knock in the engine. To understand how cetane number and knocking are related, let us see what causes knocking to occur in a diesel engine.

You will recall that, at the end of the compression stroke, the fuel system injects a spray of oil into the compressed air. The oil is not delivered all at once; it takes an appreciable time for the delivery. The oil spray starts, continues for a fraction of a second, and then stops. If the oil does not start to burn almost instantaneously, oil will continue to accumulate. Then, when the oil does ignite, there will be a considerable amount of oil present which will ignite and burn almost at the same instant. This will cause a sudden pressure rise and knock. At the same time, ignition will not be complete and smoke will appear in the exhaust gas.

If the cetane number of the fuel is high (ignition temperature low), the sprayed oil will ignite as soon as injection begins. In this case, there will be no accumulation of unburned fuel to ignite. Ignition continues evenly as the spray continues, and an even combustion-pressure rise results. But if the cetane number of the fuel is to low, there will be an ignition delay; it takes longer for the low-cetane fuel to ignite. This then results in the sudden ignition of accumulated fuel and a consequent combustion knock. Since the fuel may not have sufficient time to burn after it has started, not all of it may be burned; some will exit from the engine as smoke.

NOTE: A fuel of excessively high viscosity will also smoke. A heavy, or viscous, fuel will not atomize properly. The oil particles will be too large to burn completely, and full combustion will not take place.

§119. Cetane-number requirements The cetane number of diesel fuel must be high enough to prevent knock, as noted above. With low water-jacket temperatures, low atmospheric temperature, low compression pressures, and light-load operation a higher-cetane fuel is required. All these conditions tend to reduce compression temperature. The fuel must, therefore, have a sufficiently high cetane number (or sufficiently low ignition point) to ignite satisfactorily at these low temperatures. High-speed diesel engines require high-cetane fuels. At high speed, there is less time for the fuel to ignite; it must ignite promptly without ignition delay to prevent knocking and smoking. For starting, the lower the atmospheric temperature, the higher the cetane requirements.

§120. Fuel-oil purity The oil must have as little sulfur as possible since sulfur tends to form sulfur acids; these acids will corrode engine and fuel-system parts. Furthermore, it must be clean. Even small amounts of dirt or foreign matter are apt to cause trouble in the fuel system. The fuel system has passages and nozzles of very small size; small particles can clog them and prevent normal fuel-system and engine operation. Also, dirt particles can scratch injector parts and cause serious damage. Thus, suppliers of diesel fuel oil are very careful to hold sulfur to a minimum and to use great care in handling the oil to prevent its being contaminated.

§121. Liquefied petroleum gas Liquefied petroleum gas, or LPG, is used in more or less standard gasoline-type engines equipped with special fuel systems (see §99). LPG is made up of certain light types of hydrocarbon molecules. LPG molecules are related to gasoline molecules: both are made up of hydrogen and carbon atoms. But LPG molecules are smaller than gasoline molecules so that LPG is actually a vapor at ordinary temperatures. LPG is found in the earth along with natural gases and petroleum. It is normally liquid at the high pressures in the petroleum or gas reservoirs in the earth. When the pressure is relieved, it turns to gas. In the recovery and refining process, the LPG is separated from other gas or petroleum products and pressurized to hold it in liquid form. It is stored and transported in liquid form in pressurized tanks for convenience.

§122. Types of LPG There are actually two types of LPG that have been used for automotive-engine fuel, *propane* and *butane*. There are other LPGs, including isobutane, propylene, ethane, ethylene, and methane. But for automotive purposes either propane or butane or a mixture of the two is used.

Butane boils, or turns to vapor, at 32°F (at atmospheric pressure). Thus, it cannot be used in an LPG-type fuel system when temperatures are below 32°F. The reason for this is that at lower temperatures, it will not vaporize on its way to the carburetor. Nor will it have enough vapor pressure in the fuel tank to force it out and through the fuel lines to the carburetor.

On the other hand, propane will boil at −44°F (at atmospheric pressure). This means that, at temperatures above −44°F, it will vaporize. It will produce enough vapor pressure in the fuel tank to force it through the fuel lines and regulator to the carburetor and will enter the carburetor in vapor form, as required for normal LPG fuel-system operation.

Thus, in most parts of the country (and of course in the North) propane alone must be used for automotive fuel. In some places, butane may be mixed with propane. But in any event, the fuel must have a sufficiently low boiling point to vaporize at the air temperatures in which the vehicle operates.

§123. LPG economy Many large-scale tests of LPG as an engine fuel have been made. For instance, one large transit company operated a fleet of 500 LPG-operated busses. Trucking companies have likewise made many tests. Operating figures of gasoline, diesel, and LPG show that LPG compares favorably with the other fuels so far as cost per mile is concerned. Since LPG has a high-octane rating, it can be used in engines having compression ratios of above 10:1. This makes for efficient utilization of the fuel.

Another factor of importance is that LPG leaves little or no engine deposit when it burns in the cylinders. Also, since it enters the engine as a vapor, it cannot wash down the cylinder walls, remove lubricant, and increase cylinder-wall, piston, and piston-ring wear. Nor does it cause crankcase dilution. All these factors reduce engine wear, increase engine life, and keep maintenance costs low. However, allowances must be made for the extra cost of LPG handling equipment. The LPG must be stored in relatively heavy pressurized tanks, and special equipment must be used to fill the fuel tanks on the vehicles.

In assessing the possibilities of LPG, many engineers are predicting that LPG will come into wide use for fleet operation of busses and trucks. It will not be practical in the near future for passenger cars since it is not available everywhere, as gasoline is. Few people would want to invest in the special equipment needed to convert their car to LPG if they were not sure they could buy LPG anywhere they might like to drive.

CHECK YOUR PROGRESS

Progress Quiz 6

Once again you have a chance to stop and check your progress in learning about automotive fuel systems. The questions that follow cover essential details discussed in the past few pages. Answering the questions not only allows you to test your memory but also helps you review the important points and thereby fix them more firmly in your mind.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

Automotive-engine Fuels

1. Knocking may result from either *detonation or viscosity* *detonation or preignition* *preignition or humidity*
2. After a car with a modern high-compression engine has been driven 10,000 miles, chances are that its octane requirements will have *stayed about the same* *risen* *fallen*
3. So-called *wild* knocking, which may result from hot spots in the combustion chamber, is due to *detonation* *high octane* *preignition*
4. Two methods of satisfying the octane requirements of an engine are by *chemical and mechanical means* *full-load, full-throttle operation* *increasing compression ratio and power*
5. Factors that are of importance in lowering the mechanical octane of an engine include compression ratio, flame-travel distance in the combustion chamber, and *chemical octane* *fuel viscosity* *mixed turbulence*
6. When a diesel fuel oil will not break up into fine enough particles during spraying, so that it does not burn rapidly enough, *its viscosity is too high* *its viscosity is too low* *its cetane number is too low*
7. The ignition quality, or ease of ignition, of diesel fuel oil is referred to in terms of its *octane number* *heptane number* *cetane number*
8. A diesel fuel oil that is relatively slow to ignite when it is sprayed into the compressed air in the combustion chamber has a *relatively high cetane number* *relatively low cetane number* *relatively high octane number*
9. The two LPGs that are most widely used for automotive-engine fuel are *propane and heptane* *propane and cetane* *propane and octane* *propane and butane*
10. The LPG that can be used effectively for engine fuel in cold climates is *butane* *heptane* *propane*

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You have been making excellent progress in your studies of automotive fuel systems and fuels. The chapters that follow cover servicing procedures on the various types of fuel pumps and carburetors described in the earlier chapters. Thus, these earlier chapters form the foundation on which you can build your service-procedure knowledge. In the diagnosis of troubles and in service and repair work it always helps to know the theory behind the operation of the unit. The chapters you have already covered in the book give you this theory. Check your memory of the details covered in Chap. 7 by taking the checkup test that follows.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Important characteristics of gasoline are its *volatility and viscosity* *octane and cetane ratings* *volatility and octane rating*
2. Gasoline is blended from a number of different hydrocarbons, each with its own *cetane* *volatility* *heptane* *LPG*
3. Gasoline should have a low volatility for good economy and to combat vapor lock; for easy starting and acceleration it should have a *high volatility* *low viscosity* *high cetane* *high octane*
4. The amount that the air-fuel mixture is "squeezed" during the compression stroke is determined by the engine *stroke* *heat of compression* *compression ratio* *combustion-chamber shape*
5. Susceptibility of an engine to knocking is increased by combustion-chamber deposits as well as by *higher engine temperatures* *lower temperatures* *higher humidity*
6. Other conditions being equal, opening the throttle wide *reduces tendency to knock* *increases tendency to knock* *raises the compression ratio*
7. Characteristics of importance in diesel fuel oil are *octane and heptane* *octane and cetane* *cetane and viscosity*
8. The lower the temperature needed to ignite diesel fuel oil, the *lower the cetane number* *higher the octane number* *higher the cetane number*
9. Diesel fuel oil will smoke from incomplete combustion if the cetane number is too low or the *octane number is too high* *viscosity is too low* *viscosity is too high*
10. Among the important characteristics of LPG is the fact that it is a vapor at normal temperatures and *is a liquid at high temperatures* *has a high-octane rating* *is fast burning in combustion chamber*

Definitions and Characteristics

In the following, you are asked to write down certain definitions and characteristics that are related to various fuels discussed in the chapter.

Automotive-engine Fuels

If you have any difficulty in answering the questions, reread the pages that will give you the answer; then write down your definition. Don't copy from the book; use your own words. This is a good way to fix the explanation firmly in your mind. Write in your notebook.

1. Define volatility.
2. What is vapor lock?
3. What is compression ratio?
4. What is the effect on octane requirements as compression ratio is increased?
5. Describe one method of measuring antiknock value of gasoline.
6. What causes preignition?
7. What are some of the factors affecting knocking?
8. What is meant by mechanical octane of an engine?
9. Define viscosity.
10. What is cetane number of diesel fuel oil, and how is it related to temperature?
11. Which is the more widely used LPG for automotive vehicles, propane or butane?
12. What are some characteristics of LPG?

SUGGESTIONS FOR FURTHER STUDY

To learn more about automotive engines, refer to *Automotive Engines,* another book in the McGraw-Hill Automotive Mechanics Series. If you are interested in learning more about gasoline and other fuels, you may find books in your local public or school automotive library that can supply you with additional information. Also, manufacturers of special equipment and vehicles using LPG and diesel fuel oil issue special service manuals that supply further data on the equipment. You may be able to examine these manuals in a local truck or bus shop where this equipment is serviced. Write down in your notebook any important facts you learn.

8: Diagnosing fuel-system troubles

THE PURPOSE of this chapter is to supply detailed information on the various kinds of trouble that the fuel system has and to explain the procedures used to determine the causes of these troubles. Following chapters then describe the procedures required to make corrections.

§124. How to study this chapter There are different ways to study this chapter. You could go through it page by page, just as you have studied the previous chapters. But perhaps a better way would be to take one complaint at a time (as listed in the trouble-shooting chart), read through the possible causes and corrections, or checks, and then study the section later in the chapter that discusses the complaint. For example, you could take *1. Excessive fuel consumption,* and after reading the causes and checks or corrections listed in the second and third columns in the chart, you could turn to §137, which describes these causes and checks or corrections in more detail.

Since a knowledge of trouble causes and corrections is very helpful, you will probably be referring to the trouble-shooting chart many times. One way to help yourself remember the complaints, causes, and corrections is to write each complaint, with all or some of the causes and corrections, on a separate 3- by 5-inch card. Then you can carry the cards around with you. Whenever you have a chance, you can pull the cards out and study them. You could stick one in the mirror before you when you shave in the morning, or study one or two of them while riding the bus to work or when you are eating lunch, and so on. Soon, you will know the troubles and their causes and corrections "from A to Z."

§125. Need for logical procedure Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) describes in detail how to diagnose engine troubles and to trace them down to the faulty part or unit. If the trouble is traced down to the fuel system, some further checking may be desirable in order to pinpoint the trouble exactly. The following pages outline in detail the fuel-system checks to make as well as the corrections needed to eliminate the troubles.

It is always desirable to follow a logical procedure in diagnosing any fuel-system trouble since there are many conditions that could be the cause of a trouble. The basic complaints that might arise from faulty operation of the fuel system are described below, and under each complaint the possible causes are listed. When a specific complaint arises, then the causes under that complaint should be checked. Such a procedure saves the time and motion which might otherwise be wasted in checking things that normally would not cause the complaint.

§126. Testing instruments A variety of instruments are available for testing the fuel system and engine performance. These include fuel-mileage testers, which measure fuel consumption per mile of car travel; exhaust-gas analyzers, which check the air-fuel mixture; low-pressure gauges for measuring fuel-pump pressure; fuel-pump capacity testers; vacuum gauges for measuring fuel-pump vacuum and intake-manifold vacuum; rpm (revolutions per minute) indicators, or tachometers, for checking engine speed; and dynamometers for measuring engine power output. In addition, special tools are required for servicing the carburetor and the fuel pump.

§127. Fuel-mileage testers A complaint which is sometimes difficult to analyze is low fuel mileage. Many conditions can cause excessive fuel consumption; thus it is sometimes necessary to make an accurate measurement of the fuel consumed if the cause of the trouble appears elusive. Fuel-mileage testers vary from a fuel meter that measures fuel consumption accurately (Fig. 8-1) to a simple device that consists of a container that holds a definite amount of gasoline and a tube to connect the container to the carburetor. A simple version of the latter may be made from a can with a supporting handle for mounting under the hood and a fitting for the tube. The can must be above the carburetor so that the fuel will run from the can to the carburetor. The test is performed by disconnecting the line to the fuel tank and then operating the car until the gasoline in the carburetor is used up. The container may then be mounted and connected to the carburetor, a definite amount of gasoline being placed within the container after mounting. The car should be operated until this gasoline is used up, and an accurate mileage record should be kept.

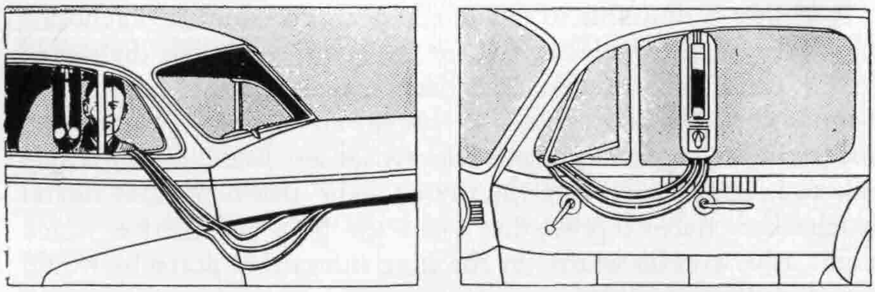


FIG. 8-1. Fuel-mileage tester as it looks from outside and inside of car when mounted in place ready for test. (*Kent-Moore Organization, Inc.*)

§128. Exhaust-gas analyzers Exhaust-gas analyzers (Fig. 8-2) are valuable in checking carburetor calibrations, adjustments, and performance. They test the exhaust gas from the engine by various methods, and this test determines whether or not the ratio of fuel and air entering the cylinders is correct, provided other components are functioning normally. As was mentioned in §115, the gasoline, composed principally of hydrogen and carbon compounds, unites with the oxygen in the air during combustion in the engine to form water (hydrogen and oxygen, H_2O), carbon dioxide (carbon and oxygen, CO_2), carbon monoxide (carbon and oxygen, CO) and negligible amounts of other products. With an ideal mixture of fuel and air entering the combustion chamber, and with perfect combustion conditions, all the oxygen in the air would unite with all the hydrogen and carbon components in the fuel to form water and carbon dioxide. This does not normally happen, however, and some unburned combustibles, as well as carbon monoxide, can invariably be found in the exhaust gas. As the ratio between the fuel and air entering the combustion chamber changes, the proportions of carbon dioxide, carbon monoxide, and unburned combustibles in the exhaust gas change. Thus, analysis of the exhaust gas gives a very accurate determination of the proportions of fuel and air entering the combustion chamber. Three types of exhaust-gas

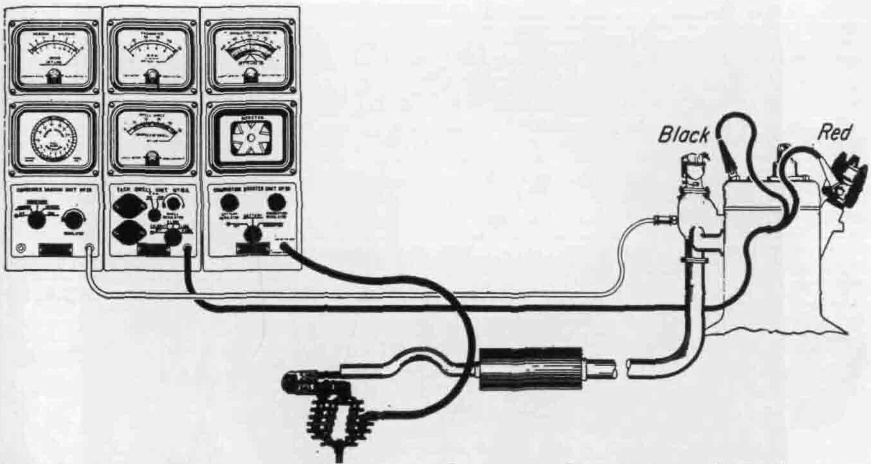


FIG. 8-2. *Instrument connections for making an exhaust-gas analysis (or combustion efficiency test).* Note that the pickup gun is installed in tail pipe and is connected by a hose to the analyzer. A small pump, or booster, draws exhaust gas through the hose to the analyzer. (*Sun Electric Corporation*)

analyzer are in use. These are the thermal-conductivity, hot-wire-catalysis, and relative-density types. A detailed analysis of their operation is contained in the Appendix.

§129. Low pressure gauges for measuring fuel-pump pressure The pressure at which the fuel pump delivers fuel to the carburetor must be within definite limits. If it is too low, insufficient fuel will be delivered and faulty engine performance will result, since the air-fuel mixture will tend to lean out excessively at high speed or on acceleration. If the pressure is too high, flooding may result, and the mixture will be too rich, causing the engine to be logy. An overrich mixture will also cause engine trouble from carbon deposits in the combustion chambers and on valves and rings. Also, crankcase dilution and rapid wear of engine parts will probably result. Fuel-pump pressure may be tested with a low-pressure gauge connected to test either static pressure or flow pressure. In the static-pressure test the gauge is connected to the outlet of the fuel pump, and the engine is run at approximately thirty mph (miles per hour) on the fuel in the carburetor while the static fuel pressure is checked. In the flow-pressure test the gauge is connected into the fuel line between the pump and the carburetor with a T fitting (Fig. 8-3), and the engine is idled with the pump delivering

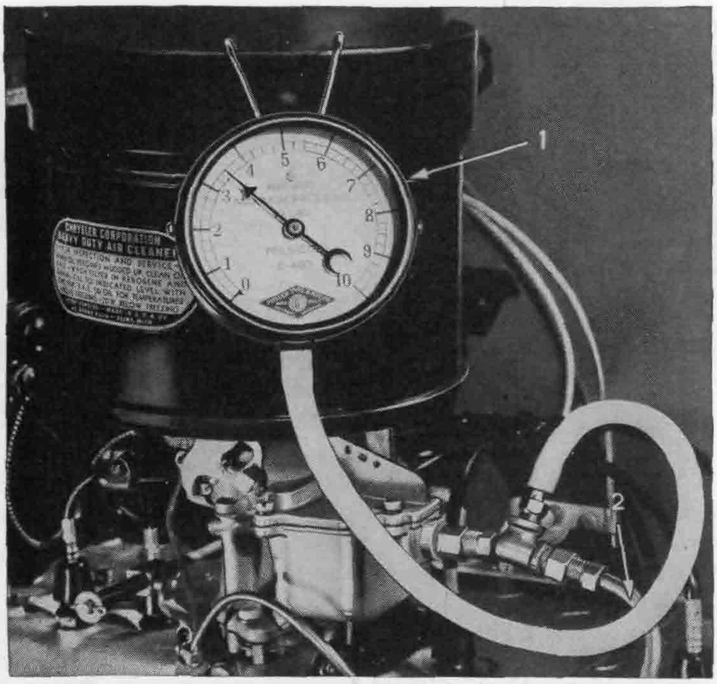


FIG. 8-3. Using a low-pressure gauge to check fuel-pump flow pressure. 1, fuel gauge; 2, line to fuel pump. (*Plymouth Division of Chrysler Corporation*)

fuel to the carburetor in the normal manner. Specifications vary considerably from one type of pump to another, but in general they will specify from 1½ to 5 pounds static pressure and about 25 percent less flow pressure.

§130. Fuel-pump capacity testers The fuel-pump capacity tester is a device that measures the amount of fuel the pump can deliver in a given time. The device is connected with a T fitting into the line at the carburetor and bleeds off a portion of the fuel passing in the line. The amount that can be bled off with the engine running is determined by the capacity and operating condition of the pump.

§131. Fuel-pump vacuum tester The fuel-pump vacuum tester is a vacuum gauge which is connected to the inlet side of the fuel pump so that the amount of vacuum the pump can produce is measured. During this test, fuel lines are disconnected from both inlet and outlet sides of the fuel pump and the engine is run temporarily on the fuel in the carburetor float bowl. The vacuum pump of the combination pump can also be tested with the vacuum gauge.

§132. Vacuum gauges for measuring intake-manifold vacuum The intake-manifold vacuum varies considerably under different operat-

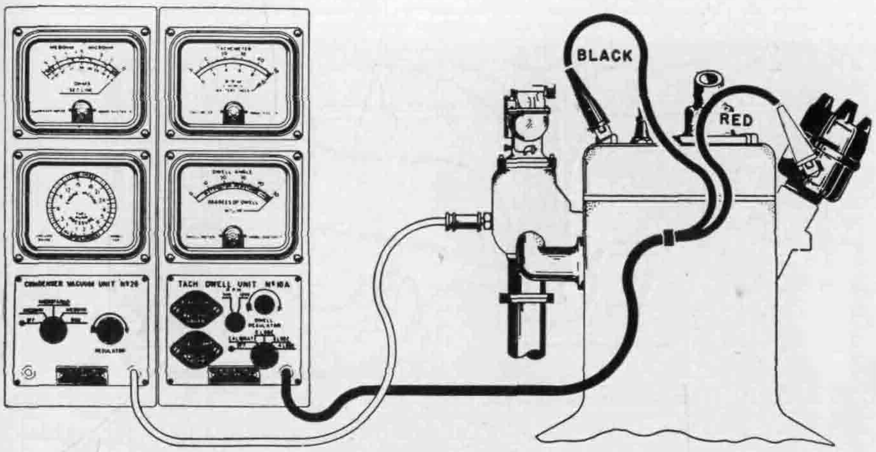


FIG. 8-4. Instrument connections for making manifold-vacuum test. The vacuum gauge shown here is built into a panel as part of a test stand. (*Sun Electric Corporation*)

ing conditions, and it also varies with faulty engine performance. The various troubles that might occur in the engine, ignition, or fuel systems are reflected by characteristic manifold-vacuum changes. Thus, a manifold-vacuum gauge that shows these changes will provide a good indication of the type of trouble (see Fig. 8-4). Faulty carburetor action, for example, is indicated by a slow oscillation of the vacuum-gauge needle or by an irregular drop from a normal reading. The procedure of testing the engine with a vacuum gauge is detailed in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*). The vacuum gauge can also be used in making the carburetor idle-mixture adjustment (§169).

§133. Tachometers Tachometers, or rpm indicators, are used to measure the speed at which the engine is running. Many engine manufacturers specify that carburetor adjustments be made so as to give an idle speed of so many engine revolutions per minute. This is particularly important on cars equipped with automatic transmissions: incorrect idle-speed settings may prevent normal action of the transmission. The tachometer used in the service shop has a pair of leads to connect into the ignition system (Fig. 8-5). Then, when the engine is running, the tachometer, in effect, counts the number of electrical impulses per minute in the ignition primary and translates this information into revolutions per minute.

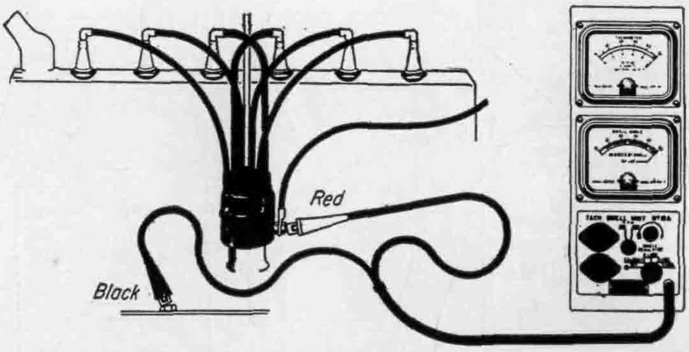


FIG. 8-5. Electric connections to check engine revolutions per minute with tachometer. Selector knob must be turned to four-, six-, or eight-lobe position, according to number of engine cylinders (or number of lobes on distributor cam). (*Sun Electric Corporation*)

An adjustment is included on the tachometer so that it can be set for four-, six-, or eight-cylinder engines.

§134. Chassis dynamometers The chassis dynamometer tests the actual power output of the engine. Since carburetor adjustments and operation, as well as many other factors, affect power output, a thorough analysis of engine performance would require a dynamometer test. This type of apparatus is shown in Fig. 8-6. The dynamometer is driven through the car rear wheels with the car in gear and the engine running.

§135. Trouble tracing in fuel system The tracing of trouble in the fuel system is usually fairly straightforward; fuel-system troubles fall into several definite classifications that require definite corrections. However, there is sometimes a question as to whether the cause of complaint lies in the fuel system or in some other engine component. Thus, the real problem is often to isolate the trouble in the improperly operating component. The trouble sometimes may be made more puzzling because it could result in not one condition but several. For example, suppose the full-power, vacuum-operated valve in the carburetor holds open. This would produce an excessively rich mixture for all running conditions except full-power, open-throttle operation. This, in turn, would not only cause excessive fuel consumption, but might ultimately foul the spark

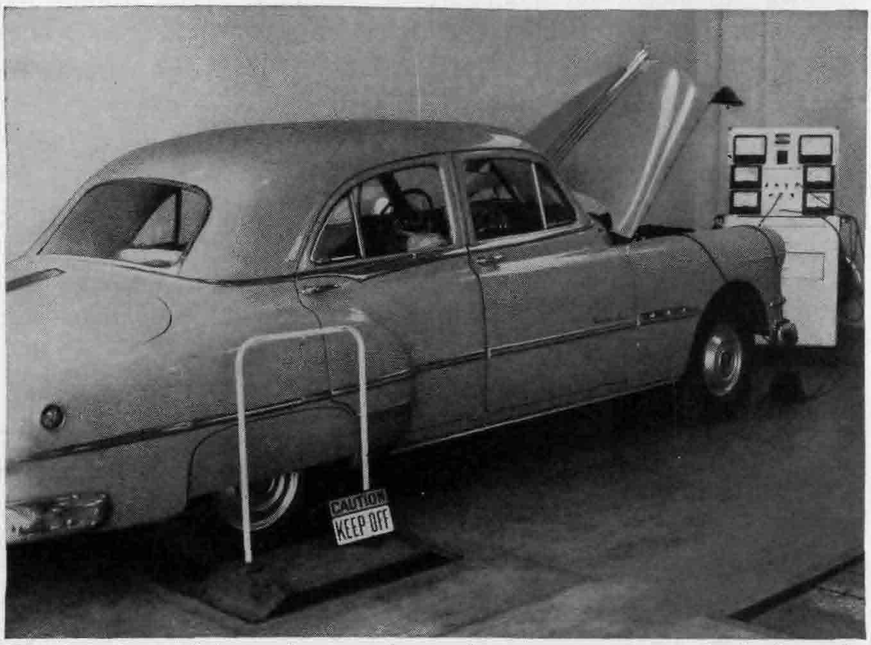


FIG. 8-6. Automobile in place on chassis dynamometer. Rear wheels drive the dynamometer rollers, and instruments on test panel indicate car speed, engine power output, engine speed, engine intake-manifold vacuum, air-fuel ratio, etc. (*Clayton Manufacturing Company*)

plugs to cause poor ignition and missing; also, the carbon deposits might cause defective piston ring and valve action.

The chart that follows lists the various troubles that might be blamed on the fuel system, together with their possible causes, checks to be made, and corrections needed. This chart might be considered as a further development of the comprehensive trouble-shooting chart contained in *Automotive Engines* (another book in the McGraw-Hill Automotive Mechanics Series).

§136. Fuel-system trouble-shooting chart Most fuel-system troubles can be listed under a few headings: excessive fuel consumption, poor acceleration, lack of power and high-speed performance, poor idle, engine will not start except when primed, hard starting, slow warm-up, stalling, smoky exhaust, and backfiring. The chart that follows lists possible causes of each of these troubles, and then refers to numbered sections after the chart for fuller explanations of the way to locate and eliminate the troubles. When trouble has been traced to some component outside the fuel system, reference is made to the book in the McGraw-Hill Automotive Mechanic Series that provides necessary servicing information.

NOTE: The troubles and possible causes are not listed in the chart in the order of frequency of occurrence. That is, item 1 (or item *a* under Possible Causes) does not necessarily occur more frequently than item 2 (or item *b*). Generally, the fuel-system troubles and possible causes are listed first in the chart even though, in many cases, other automotive components are more apt to have caused the troubles listed.

FUEL-SYSTEM TROUBLE-SHOOTING CHART

(See §§137 to 147 for detailed explanations of trouble causes and corrections listed below.)

Complaint	*Possible Cause*	*Check or Correction*
1. Excessive fuel consumption (§137)	*a.* Nervous or "jack-rabbit" driver	Drive more reasonably
	b. High speed	Drive more slowly
	c. Short-run and "start and stop" operation	Make longer runs
	d. Excessive fuel-pump pressure or pump leakage	Reduce pressure; repair pump
	e. Choke not opened properly	Open; repair or replace automatic choke
	f. Clogged air cleaner	Clean
	g. High carburetor float level or float leaking	Adjust or replace float

Complaint	*Possible Cause*	*Check or Correction*
1. Excessive fuel consumption (§137)	*h.* Stuck or dirty float needle valve	Free and clean or replace
	i. Worn carburetor jets	Replace
	j. Stuck metering rod or full-power piston	Free
	k. Idle too rich or too fast	Readjust
	l. Stuck accelerator pump check valve	Free
	m. Carburetor leaks	Replace damaged parts; tighten loose couplings, jets, etc.
	n. Faulty ignition	Check coil, condenser, plugs, contact points, wiring*
	o. Loss of engine compression	Check compression; repair engine†
	p. Defective valve action	Check compression; repair engine†
	q. Excessive rolling resistance from low tires, dragging brakes, wheel misalignment, etc.	Correct cause of rolling resistance‡
	r. Clutch slipping	Adjust or repair clutch§
2. Engine lacks power, acceleration, or high-speed performance (§138)	*a.* Accelerator pump malfunctioning	Adjust; free; repair
	b. Power step-up on metering rod not clearing jet	Free or adjust
	c. Power piston or valve stuck	Free
	d. Low float level	Adjust
	e. Dirt in filters or in line or clogged fuel-tank-cap vent	Clean

* See *Automotive Electrical Equipment.*
† See *Automotive Engines.*
‡ See *Automotive Chassis and Body.*
§ See *Automotive Transmissions and Power Trains.*

Complaint	*Possible Cause*	*Check or Correction*
2. Engine lacks power, acceleration, or high-speed performance (§138)	*f.* Choke stuck or not operating	Adjust or repair
	g. Air leaks around carburetor	Replace gaskets; tighten nuts or bolts
	h. Antipercolator valve stuck	Free; adjust
	i. Manifold heat-control valve stuck	Free
	j. Throttle valve not fully opening	Adjust linkage
	k. Rich mixture due to worn jets, high float level, stuck choke, clogged air cleaner	Adjust; repair; clean; replace worn jets
	l. Vapor lock	Use different fuel or shield fuel line
	m. Fuel pump defective	Service or replace
	n. Clogged exhaust	Clean
	o. Ignition defective	Check timing, coil, plugs, distributor, condenser, wiring*
	p. Loss of compression	Check engine compression; repair engine†
	q. Excessive carbon in engine	Clean out†
	r. Defective valve action	Check compression; repair engine†
	s. Heavy engine oil	Use lighter oil
	t. Cooling system not operating properly	Check thermostat; flush system (see §§249 to 252)
	u. Engine overheats	Check cooling system (see §251)
	v. Excessive rolling	Correct the defect

* See *Automotive Electrical Equipment.*
† See *Automotive Engines.*
‡ See *Automotive Chassis and Body.*
§ See *Automotive Transmissions and Power Trains.*

Complaint	*Possible Cause*	*Check or Correction*
2. Engine lacks power, acceleration, or high-speed performance (§138)	resistance from low tires, dragging brakes, wheel misalignment, etc.	causing rolling resistance‡
	w. Clutch slippage or excessive friction in power train	Adjust or repair§
3. Poor idle (§139)	*a.* Idle mixture or speed not adjusted	Readjust
	b. Other causes listed under *Engine lacks power, etc.* (item 2, above)	
4. Engine will not start except when primed (§140)	*a.* Line clogged	Clear
	b. Fuel pump defective	Repair or replace
	c. Carburetor jets or lines clogged	Clean
	d. Filter clogged	Clean
	e. Air leaks into intake manifold or carburetor	Replace gaskets; tighten nuts or bolts
5. Hard starting with engine warm (§141)	*a.* Choke valve closed	Open; adjust or repair
	b. Manifold heat-control stuck closed	Open; free valve
	c. Throttle-cracker linkage out of adjustment	Adjust
	d. Vapor lock	Use correct fuel or shield fuel line
	e. Engine parts binding	Repair engine†
6. Slow engine warm-up (§142)	*a.* Choke valve open	Adjust or repair
	b. Manifold heat-control valve stuck open	Close; free valve
	Cooling-system thermostat stuck open	Free; replace if necessary

Complaint	*Possible Cause*	*Check or Correction*
7. Smoky, black exhaust (§143)	*a.* Very rich mixture	(see §137 on excessive fuel consumption)
	NOTE: A blue exhaust means excessive oil consumption (see §227)	
8. Engine stalls when cold or as it warms up (§144)	*a.* Choke valve stuck or choke inoperative	Free; adjust
	b. Manifold heat-control valve stuck closed	Open; free
	c. Engine overheats	(see §251)
9. Engine stalls after idling or slow-speed driving (§144)	*a.* Defective fuel pump	Repair or replace
	b. Engine overheats	(see §251)
10. Engine stalls after high-speed driving (§144)	*a.* Vapor lock	Use different fuel or shield fuel line
	b. Antipercolator malfunctioning	Adjust or repair
	c. Engine overheats	(see §251)
11. Engine backfires (§145)	*a.* Excessively rich or lean mixture	Repair or readjust fuel pump or carburetor
	b. Overheating of engine	(see §251)
	c. Engine conditions such as excessive carbon, hot valves, overheating	Repair engine†
	d. Ignition timing incorrect	Retime*
	e. Spark plugs of wrong heat range	Install correct plugs*
12. Engine runs but misses (§146)	*a.* Fuel pump erratic in operation	Repair or replace
	b. Carburetor jets or lines clogged or worn	Clean or replace

* See *Automotive Electrical Equipment.*
† See *Automotive Engines.*

Complaint	*Possible Cause*	*Check or Correction*
12. Engine runs but misses (§146)	*c.* Fuel level not correct in float bowl	Adjust float; clean needle valve
	d. Ignition system defects such as incorrect timing or defective plugs, coil, points, cap, condenser, wiring	Check ignition system*
	e. Clogged exhaust	Check tail pipe, muffler; eliminate clogging
	f. Engine overheating	(see §251)
	g. Engine conditions such as valves sticking, loss of compression, defective rings, etc.	Check engine†

§137. Excessive fuel consumption The first step in analyzing a complaint of excessive fuel consumption is to make sure that the car is really having this trouble. Usually, this means taking the word of the car owner that his car is using too much fuel. A fuel-mileage tester (§127) can be used to determine accurately how much fuel the car is using. After it has been determined that the car is using too much fuel, then the cause of trouble must be found. It could be in the fuel system, ignition system, engine, or elsewhere in the car.

The compression tester and the intake-manifold vacuum gauge, described in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*), will determine the location of trouble and whether it is in the fuel system, ignition system, engine, or elsewhere.[1]

If the trouble appears to lie in the fuel system, the following points should be considered.

1. A nervous driver or one who pumps the accelerator pedal

[1] A rough test of mixture richness that does not require any testing instruments is to install a set of new or cleaned spark plugs of the correct heat range for the engine. Then take the car out on the highway for 15 or 20 minutes. Stop the car, remove and examine the plugs. If they are coated with a black carbon deposit, the indication is that the mixture is too rich. See points 4 to 7, §137.

when idling and "jack-rabbits" when starting because he insists on being the first to get away when the stop light changes uses an excessive amount of fuel. Each downward movement of the accelerator pedal causes the accelerator pump to discharge a flow of gasoline into the carburetor air horn. This extra fuel is wasted since it contributes nothing to the movement of the car.

2. High-speed operation requires more fuel per mile. A car that will give 20 miles per gallon at 30 mph may give less than 15 miles per gallon at 60 mph. At 70 or 80 mph the mileage may drop to well below 10 miles per gallon. Thus, a car operated consistently at high speed will show poorer fuel economy than a car driven consistently at intermediate speed.

3. Short-run, "stop and start" operation uses up more fuel. In short-run operation, with the engine allowed to cool off between runs, the engine is operating mostly cold or on warm-up. This means that fuel consumption is high. When the car is operated in heavy city traffic, or under conditions requiring frequent stops and starts, the engine is idling a considerable part of the time. Also, the car is accelerated to traffic speed after each stop. All this uses up a great deal of fuel, and fuel economy will be poor.

4. If the fuel pump has excessive pressure, it will maintain an excessively high fuel level in the carburetor float bowl. This will cause a heavier discharge at the fuel nozzle or jet, thereby producing high fuel consumption. Excessive pump pressure is not a common cause of excessive fuel consumption, however, since it could result only from installation of the wrong pump or diaphragm spring or from incorrect reinstallation of the pump diaphragm during repair. However, pumps can develop leaks that will permit loss of gasoline to the outside or into the crankcase; this requires replacement of the diaphragm, tightening of the assembling screws, or replacement of the pump (§158 to 165).

5. If a manually operated choke is left partly closed, the carburetor will deliver too much fuel for a warm engine, and fuel consumption will be high. On manually operated chokes, it is possible for the choke-valve linkage to get out of adjustment, so that the valve will not open fully; this will require readjustment to prevent high fuel consumption (§150).

With an automatic choke, the choke valve should move from closed to open position during engine warm-up, reaching full-open position when the engine reaches operating temperature. This action can be observed by removing the air cleaner and noting the changing position of the choke valve during warm-up. If the automatic choke does not open the choke valve normally, excessive fuel will be used. The choke must be serviced (§§151 to 153).

6. A clogged air cleaner (on unbalanced carburetor) acts much like a closed choke valve (see §57) since it chokes off the free flow of air through it. The cleaner element should be cleaned or replaced and fresh oil added (on type of cleaner using oil). See §149.

7. In the carburetor itself, the following conditions could cause delivery of an excessively rich air-fuel mixture (see Chap. 10, "Carburetor Service," for corrections).

a. High float level or leaking float will permit delivery of too much fuel to the float bowl and consequently through the fuel nozzle or jet. The float level must be readjusted or a leaky float replaced.

b. A stuck or dirty float needle valve will not shut off the flow of fuel from the fuel pump, so that too much will be delivered through the carburetor fuel nozzle or jet. The needle valve should be freed and cleaned or replaced.

c. Worn carburetor jets pass too much fuel causing the air-fuel mixture to be too rich. Worn jets must be replaced.

d. If the full-power circuit operates during part-throttle operation, too much fuel will be delivered through the main fuel nozzle. This could be due to a stuck metering rod or full-power piston, which must be freed.

e. An idle that is set too rich or too fast wastes fuel. Resetting of the idle richness and speed is required.

f. If the accelerator-pump check valve sticks open, it may permit discharge of fuel through the pump system into the carburetor air horn, causing excessive fuel consumption. This requires freeing and servicing of the check valve.

g. Carburetor leaks, either internal or external, cause loss of fuel. Correction is to replace gaskets or damaged parts and tighten loose couplings on fuel lines, loose jets or nozzles, and loose mounting nuts or screws.

8. Faulty ignition can also cause excessive fuel consumption since the ignition system could cause engine miss and thus failure of the engine to utilize all the fuel. This type of trouble would also be

associated with loss of power, acceleration, or high-speed performance (§138). Conditions in the ignition system that might cause the trouble include a "weak" coil or condenser, incorrect timing, faulty advance mechanism action, dirty or worn spark plugs or contact points, and defective wiring.

9. Several conditions in the engine can also produce excessive fuel consumption. Loss of engine compression from worn or stuck rings, worn or stuck valves, or a loose or burned cylinder-head gasket causes loss of power. This means that more fuel must be burned to achieve the same speed or power.

10. Any condition that increases rolling resistance and makes it harder for the car to move along the road will increase fuel consumption. For example, low tires, dragging brakes, and misalignment of wheels increase fuel consumption. Similarly, losses in the power train, as, for instance, from a slipping clutch, will increase fuel consumption.

§138. Engine lacks power, acceleration, or high-speed performance This type of complaint is usually rather difficult to analyze since it is, after all, somewhat vague. Almost any component of the engine or car, from the driver to the tires, could cause the complaint. As a first step in solving this sort of complaint, some mechanics take the car out for a road test. The car can be accelerated over a good road with a stop watch used to determine how long it takes to reach a given speed. The test should be made on the road first in one direction and then in the other and the results averaged, so that such variables as wind and road grade are balanced out. The engine can also be checked on the chassis dynamometer (§134) or be given a comprehensive tune-up as detailed in *Automotive Engines* (another book in the McGraw-Hill Automotive Mechanics Series).

Conditions that might cause the complaint are discussed in following paragraphs, with the fuel-system conditions considered first.

1. Almost any out-of-balance condition in the carburetor could prevent delivery of proper amounts of fuel for good acceleration and full power. Possibilities to be considered follow (see Chap. 10, "Carburetor Service").

a. Incorrect functioning of the accelerator pump. On many engines the action of the accelerator pump can be checked by removing the air cleaner and observing the accelerator-pump discharge jet when the throttle is opened. If the pump is functioning correctly, a steady stream of fuel will be discharged from the jet as the throttle is opened. The stream should continue for some moments after the throttle has reached full-open position. If the pump does not operate correctly, disassembly and servicing is required. Some pumps can be adjusted to change the amount of fuel delivered during acceleration.

b. If the power step-up diameter on the metering rod does not clear the metering-rod jet with wide-open throttle, insufficient fuel will be delivered for full-power performance. This requires readjustment of metering-rod linkage.

c. Similarly, if the full-power piston or valve sticks so that the valve cannot open for full power, insufficient fuel will be delivered. The piston or valve must be freed and cleaned.

d. A low float-level adjustment will "starve" the main nozzle or jet, preventing delivery of normal amounts of fuel and causing loss of engine power. The float level should be readjusted.

e. Dirt in filters or line will also "starve" the carburetor main nozzle or jet and the engine since it will tend to restrict fuel passage. Also, a clogged fuel-tank-cap vent will restrict the passage of air into the tank as gasoline is withdrawn. This creates a partial vacuum in the tank that works against the pump; fuel delivery to the carburetor is cut down. Dirt must be cleaned out of the cap vent, filters, and line.

f. A stuck or inoperative choke will cause loss of power when the engine is cold. It may also cause loss of power with the engine hot if it is stuck in a partly closed position, since this produces an excessively rich mixture. The choke should be serviced.

g. If air leaks into the intake manifold around the carburetor or manifold mounting, or past worn throttle-shaft bearings, the air-fuel mixture may become too lean for good operation. Gaskets should be replaced and mounting nuts or screws tightened as necessary. Excessively worn throttle-shaft bearings require carburetor body replacement.

h. A stuck antipercolator valve may also cause an excessively lean mixture and requires freeing or adjustment.

i. A stuck manifold heat-control valve, if stuck in the closed position, overheats the air-fuel mixture in the intake manifold with the engine hot, so that the mixture expands excessively. This "starves" the engine, causing inferior performance. If the valve sticks open, warm-up will be slowed. The valve should be freed.

j. If the throttle-valve linkage is out of adjustment, the throttle may not open fully, preventing delivery of full power. Throttle linkage should be correctly adjusted (§168).

k. Most of these conditions produce an excessively lean mixture. However, conditions that produce an excessively rich mixture (see §137) also cause poor engine performance.

2. Vapor lock also causes fuel "starvation" in the engine. Vaporization or boiling of the fuel in the fuel pump or fuel line prevents delivery of normal amounts of fuel to the carburetor and carburetor nozzles and jets. Some mechanics check for this condition by inserting a glass tube in the fuel line and then watching for bubbles to pass through the tube with the engine hot and running. Correction is to use a fuel with lower volatility or to shield the fuel line from engine heat.

3. A defective fuel pump might also "starve" the engine by not delivering sufficient amounts of fuel to the carburetor. This requires servicing or replacement of the fuel pump (§§157 to 165).

4. A clogged exhaust due to rust, dirt, or mud in the muffler or tail pipe or a pinched or damaged muffler or tail pipe could create sufficient back pressure to prevent normal exhaust from the engine. This would result in reduced engine performance, particularly on acceleration or at high speed.

5. Defective ignition can reduce engine performance, just as it can increase fuel consumption (§137, 8). Conditions in the ignition system that might cause the trouble include a "weak" coil or condenser, incorrect timing, faulty advance mechanism action, dirty or worn spark plugs or contact points and defective wiring.

6. A sluggish engine will result from loss of compression, excessive carbon in the engine cylinders, defective valve action, or heavy engine oil.

7. Failure of the cooling system to operate properly could cause the engine to overheat with a resulting loss of power (§251). Also, if the cooling-system thermostat fails to close as the engine cools,

it will prolong engine warm-up the next time the engine is started. This reduces engine performance during warm-up.

8. Any condition that increases rolling resistance will reduce acceleration and top speed. These conditions include low tires, dragging brakes, and misalignment of wheels.

9. Clutch slippage or excessive friction in the power train will reduce acceleration and top speed.

§139. Poor idle If the engine idles roughly, too slow, or too fast, the probability is that the idle mixture and idle speed require adjustment as explained in §168. In addition, a malfunctioning choke, a high or low float level, vapor lock, clogged idle circuit, air leaking into the intake manifold, loss of engine compression, improper valve action, overheating engine, improperly operating ignition system, all of which were discussed in the previous section, would cause poor idle. These latter conditions, however, would also cause poor engine performance at speeds above idle. Improper idle-mixture or idle-speed adjustment becomes obvious only with the engine idling.

§140. Engine will not start except when primed When the engine turns over at normal cranking speed but will not start, the trouble is probably in the ignition or fuel system. The ignition system can be quickly checked by disconnecting the lead from one spark plug and holding the lead clip about three-sixteenths of an inch from the engine block while cranking. If a good spark occurs, the ignition system is probably operating normally, although it could be out of time (see *Automotive Electrical Equipment*).

If the ignition system operates normally, the engine should be primed by removing the air cleaner and squirting a small amount of fuel from an oil can into the carburetor air cleaner while cranking.

Caution: Gasoline is highly explosive. Keep back out of the way when priming the engine; the engine might backfire through the carburetor.

If the engine starts and runs when primed, failure to run normally means that the carburetor is not delivering fuel to the engine. This could be due to clogged lines or jets in the carburetor, a clogged filter, a defective fuel pump, clogged fuel line, or an empty fuel tank. Pump action may be tested by temporarily loosening the fuel line at the carburetor and then cranking briefly to see if the fuel pump is delivering fuel. (Catch fuel in a container or cloth, and then put cloth outside to dry.)

If the fuel pump does not deliver fuel, it must be removed for repair (§§157 to 165). If the fuel pump does deliver fuel, the carburetor is defective, and it must be serviced (see Chap 10, "Carburetor Service").

§141. Hard starting with engine warm If the engine starts hard when warm, it could be due to the choke sticking closed, improper throttle-cracker linkage, vapor lock (§138, 2), or engine binding due to overheating. Choke action can be watched with the air cleaner removed. If the choke does not open wide with the engine hot, it should be serviced (§§151 to 153).

§142. Slow engine warm-up If the engine warms up slowly, the trouble could be due to an open choke (it should be partly closed with the engine cold); this can be seen with the air cleaner off. Also, the manifold heat-control valve or the cooling-system thermostat could be stuck open.

§143. Smoky, black exhaust A smoky, black exhaust means that the air-fuel mixture is very rich. Not only does this greatly increase fuel consumption, but also it causes rapid formation of carbon in the engine cylinders, fouling of plugs, and sticking of valves. Section 137, which discusses fuel consumption, describes various causes of the trouble.

NOTE: A smoky, blue exhaust means excessive oil consumption (§227).

§144. Engine stalls The engine will stall under various conditions, and as a first step in determining the cause, the condition under which it stalls should be noted.

1. If the engine stalls when cold, the choke may not be closed as it should be with the engine cold. Choke action should be checked and adjustment made as necessary (§§150 to 153).
2. If the engine stalls as it warms up, the choke could be stuck closed, causing an overrich mixture; or the manifold heat-control valve could be stuck closed; or the engine may be overheating.
3. If the engine stalls after idling or slow-speed driving, the chances are that the fuel pump is defective and has a cracked

diaphragm, weak spring, or defective valve. In such case, the pump cannot deliver enough fuel at low speed to replace that delivered by the engine. The carburetor float bowl runs dry and the engine stops. In addition, the engine may overheat during sustained idling or slow-speed driving since with this type of operation air movement through the radiator may not be great enough to keep the engine cool.

4. If the engine stalls after a period of high-speed or full-power driving, it may be due to vapor lock (§138, 2), malfunctioning of the antipercolator, which causes excessive richness and will require adjustment, or overheating of the engine.

§145. Engine backfires It is not uncommon for backfiring to occur in a cold engine, due to a temporarily improper air-fuel-mixture ratio or to sluggish intake valves. However, after the engine has started and is warming up, backfiring becomes a more serious matter. It may be due to an excessively rich or lean mixture which will not ignite properly, causing backfiring through the carburetor. Backfiring may also be due to preignition caused by such engine conditions as hot valves or excessive carbon, as well as such ignition-system conditions as incorrect timing or plugs of the wrong heat range.

§146. Engine runs but misses If the engine runs but misses, it is possible that the fuel system is erratic in its action so that fuel delivery is not uniform. This could result from clogged fuel lines, clogged nozzles or circuits in the carburetor, incorrectly adjusted or malfunctioning float levels or needle, or an erratic fuel pump. Other conditions that might cause missing include ignition defects such as incorrect timing or defective plugs, coil, points, cap, condenser, or wiring. The exhaust might be clogged, causing back pressure that prevents normal air-fuel-mixture delivery to the cylinders. Also, the engine might be overheating, or it might have sticky valves, loss of compression, defective piston rings, and so on.

§147. Quick carburetor checks A number of quick checks can be made that will give a rough idea of whether the various carburetor circuits are functioning satisfactorily. The results of these checks should not be considered final. Accurate analysis of carburetor operation requires the use of an exhaust-gas analyzer and an intake-manifold vacuum gauge. (See the footnote in §137 for the spark-plug test for an excessively rich mixture.)

1. Float-level adjustment. With the engine running at idling speed, remove the air cleaner, and note the condition of the high-speed nozzle. If the nozzle tip is wet or is discharging gasoline, the probability is that the float level is high, causing a continuous discharge of gasoline from the nozzle.

2. Low-speed and idle circuits. If the engine does not idle smoothly, the idle circuit is malfunctioning. Slowly open the throttle to give about 25 mph engine speed. If the speed does not increase evenly and the engine runs roughly through this speed range, the low-speed circuit is out of order.

3. Accelerator-pump circuit. Open the throttle suddenly and note whether the accelerator-pump circuit discharges a flow of gasoline into the air horn. The flow should continue a few moments after throttle reaches open position. On some carburetors this may be better observed with the engine not running.

4. High-speed circuit. With the engine running at approximately 25 mph, slowly cover part of the air horn with the hand. The engine should speed up slightly, since this should cause a normally operating high-speed circuit to discharge more gasoline. The high-speed circuit is probably working improperly if the engine does not speed up somewhat.

CHAPTER CHECKUP

The chapter you have been studying is probably one of the most difficult in the book. At the same time it is perhaps the most important. For, to be an expert automotive mechanic, you need to know how to find causes of trouble in the engine and fuel system. The fact that you have come this far in the book indicates that you have made a fine start toward becoming an expert on fuel systems. The checkup below will help you find out how well you are remembering what you have been studying on the subject of trouble-shooting in the fuel system. It will also help you review the important points and fix them more firmly in your mind. If any of the questions seem hard, just reread the pages that will give you the answer.

Correcting Troubles Lists

The purpose of this exercise is to help you to spot related and unrelated troubles on a list. For example, in the list, *excessive fuel consumption:*

high speed operation, start and stop operation, high float level, low speed operation, worn carburetor jets, you can see that *low speed operation* is the only condition that would not cause high fuel consumption. Thus, it does not belong on the list. Any of the other conditions increases fuel consumption.

In each of the lists, you will find one item that does not belong. Write down each list in your notebook, but *do not write down* the item that does not belong.

1. Engine lacks power: throttle linkage out of adjustment, air leaks into intake manifold, metering rod or power piston stuck, high-octane fuel, low float level.
2. Excessive fuel consumption: clogged air cleaner, short-run operation, high-speed operation, stuck metering rod or full-power piston, idle speed too low, accelerator-pump check valve stuck open.
3. Poor idle: idle mixture too lean, idle speed too low, loss of engine compression, engine too hot, accelerator pump inoperative.
4. Engine will not start except when primed: line clogged, fuel pump defective, carburetor jets clogged, spark plugs defective, filter clogged.
5. Hard starting with engine warm: choke valve closed, vapor lock, engine parts binding, cooling-system thermostat stuck, manifold heat-control valve stuck.
6. Engine stalls as it warms up: choke valve stuck closed, manifold heat-control valve stuck, engine overheating, heavy engine oil.
7. Engine stalls after idling: defective fuel pump, engine overheating, hot engine valves.
8. Engine stalls after high-speed driving: vapor lock, engine overheating, antipercolator malfunctioning, carbon in engine.
9. Engine backfires: lean mixture, rich mixture, engine overheating, excessive carbon, hot valves, high-octane fuel.
10. Engine runs but misses: fuel-pump action erratic, carburetor jets clogged, engine overheating, ignition-system defects, excessive rolling resistance, clogged exhaust.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The fuel-mileage tester measures *miles per hour* *miles per gallon* *miles per minute* *the fuel pump*

2. Exhaust-gas analyzers test *intake-manifold pressure* *fuel-pump action* *exhaust gases* *intake mixture*
3. Worn carburetor jets or a clogged air cleaner will cause *full-power operation* *high fuel consumption* *spark knock* *fast engine warm-up*
4. Excessive rolling resistance will *reduce fuel consumption* *reduce top speed* *reduce idle speed* *reduce float-level height*
5. If the engine will not start except when primed, a possible cause is a *defective choke* *defective accelerator pump* *defective fuel pump*
6. If the engine starts hard when warm, a possible cause is *defective choke* *excessive rolling resistance* *heavy engine oil* *high-octane fuel*
7. Slow engine warm-up may be due to *stuck accelerator pump* *stuck-fuel pump* *stuck choke valve*
8. A smoky, black exhaust is due to *lean mixture* *overheated engine* *vapor lock* *very rich mixture* *stuck engine valves*
9. Engine stalling after high-speed driving may be due to *vapor lock* *high compression* *excessive fuel-pump pressure*
10. Engine backfiring could result from *excessive rolling resistance* *loss of compression* *improper mixture ratio* *defective oil pump*
11. Engine missing could be caused by *high compression* *high-octane fuel* *fuel pump erratic*
12. An excessively rich mixture will *cause excessive rolling resistance* *cause fouled spark plugs* *increase engine efficiency* *damage fuel pump*
13. If the high-speed nozzle in the carburetor air horn is discharging gasoline when the engine is running at idling speed, then probably the *float level is high* *float level is low* *fuel line is clogged* *accelerator pump is defective*
14. Poor fuel economy means *less high-speed operation* *less fuel-pump pressure* *less miles per gallon* *less gallons per mile*
15. If the engine stalls after a period of idling, it is probably due to a defective *oil pump* *water pump* *fuel pump* *air pump*

Trouble-shooting Fuel-system Complaints

The following questions are "stumpers" that you might actually encounter in the automotive shop. That is, as an automotive mechanic, you might come up against complaints of high fuel consumption, loss of power, engine stalling, and so on, and you would have to know what to do to find the cause and eliminate it. In the following questions, you are asked to write down the procedures you would follow if various troubles were reported to you. If you are not quite sure of a procedure, turn back to the pages in the chapter that will give you the information. Then write it down in your notebook. Do not copy, but write it in your own words. This will help you remember the procedures.

1. A man brings his car into your shop and complains about low gasoline mileage. He is very impatient and keeps "gunning" the accelerator while he talks to you. What might you suspect is the trouble? What other driving conditions increase fuel consumption?
2. How does improper choke action increase fuel consumption?
3. If you suspected that the cause of poor fuel economy was in the carburetor, what are the things you would look for?
4. What are some of the conditions, not in the fuel system, that might increase fuel consumption?
5. A man drives his car into your shop and complains that he cannot get more than about 55 or 60 mph although he used to get 15 or 20 mph more. What are some of the conditions, in the fuel system, as well as elsewhere, that you should consider?
6. When an engine will turn over but will not start, what ignition test can you make? What fuel-system test?
7. You are called out into the country to a stalled car and find that the engine, when primed, turns over normally and will run. What would you do then to try and find the trouble?
8. If an engine stalls when it warms up, where would you look for the trouble?
9. You are called out to bring in a stalled car. The owner tells you that it had been running all right but when he stopped in the driveway and left the engine running while he talked some business over with a prospect, it stalled. There is fuel in the tank, and the engine does not seem to be overheated. Where would you look for trouble?
10. An engine is backfiring badly. Where would you look for trouble?
11. What are some of the causes of a missing engine?
12. You are called out to bring in a car that will not start. The owner tells you that he had been out driving all morning and that he came home, stopped for a moment, and then tried to start. The engine wouldn't start. However, when you try to start, it starts easily. It took you at least an hour to get to the car after the owner called you. What do you think might be the trouble?
13. What is a quick check to determine if the float level is too high?

14. What is a quick check of the high-speed circuit?
15. What is a quick check of the accelerator-pump circuit?

SUGGESTIONS FOR FURTHER STUDY

Careful observation of checking and trouble-shooting procedures in an automotive service shop, plus examination of components and parts that have caused trouble, will be of great value to you. This will help you link cause and effect together. For instance, if you can examine a fuel pump with a cracked diaphragm, you will be able to see why it would not deliver enough fuel to the carburetor, causing starvation of the engine.

It will be a great asset to you if you know thoroughly the trouble-shooting procedures in the chapter. One way of helping yourself remember them, as we have already suggested, is to write the procedures or the causes and effects down on 3- by 5-inch cards and carry these cards around with you. At odd moments, as, for instance, when you are riding on a bus, eating a sandwich, or getting ready for work, you can take out a card and read it over. Soon you will know the various causes of excessive fuel consumption or loss of power and other troubles in the engine and fuel system.

Be sure to talk with expert automotive mechanics and your instructor about the various methods of locating troubles in engines. Ask them about their experiences in locating troubles, how often they find loss of power is due to defects in the fuel system, whether fuel pumps are causing them much trouble, and so on.

9: Fuel-system service

THIS CHAPTER deals with fuel-system service and covers all fuel-system components except carburetors. Carburetor service is described in a following chapter (Chap. 10). Special tools are required to perform many of the fuel-system service jobs. Such special tools are described on the following pages where the service jobs are covered. In addition, several common hand tools are needed. These common hand tools are described in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*). Refer to that book for information on them.

§148. Cleanliness The major enemy of good service work is dirt. A trace of dirt in the wrong place in a carburetor or fuel pump may cause serious difficulty. For example, dirt in the needle-valve seat in the carburetor float bowl may prevent closing of the needle valve; the float bowl will overfill and cause an excessively rich mixture and high fuel consumption. Similarly, dirt in the idle circuit or accelerator-pump system may produce malfunctioning of the carburetor and inferior engine operation. Thus, when you are repairing a fuel pump or a carburetor, you should be sure that your hands, the repair bench, and the repair tools are really clean. In addition to this precaution, there are two other cautions to observe, as follows.

Caution 1: It is often the practice to use an air hose to air-dry carburetor and fuel-pump parts after they have been washed in cleaning compound and also to blow out carburetor circuits. When using an air hose, remember that the air stream drives dirt particles before it at high velocity. Such particles could get into the eyes and injure them. Be very careful where you point the hose. To be on the safe side, many automotive mechanics wear safety goggles to protect their eyes when they use the air hose. This is good safety practice and you should follow it.

Caution 2: *Never forget that gasoline vapor is highly explosive.* Use extreme care in handling fuel-system parts that may be covered or filled with gasoline. When removing a carburetor, fuel pump, filter, or fuel tank, drain it into a container and then wipe up all spilled gasoline with cloths. Put the cloths outside to dry. *Never bring an open flame near gasoline!* This could result in a disastrous fire.

§149. Air-cleaner service The air cleaner (Fig. 9-1) passes a tremendous amount of air through its filter element. The filter element constantly removes dirt and dust from the air; this dirt gradually accumulates in the element and clogs it. On the oil-bath

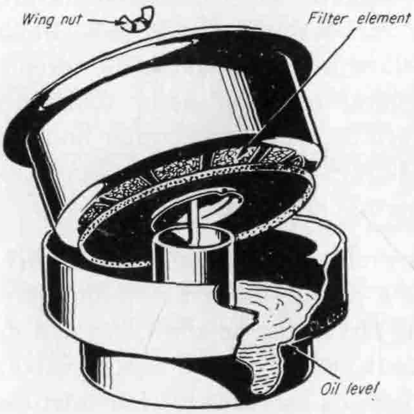


FIG. 9-1. Air cleaner with wing nut and filter element removed and the side partly cut away to show oil level.

type of cleaner, much of this dirt is washed down into the oil so that the oil gradually becomes dirty. To prevent loss of cleaner efficiency, the cleaner must be removed from the carburetor periodically and cleaned.

Cleaners are attached by a wing nut clamp, or screw clamp. In addition, many cleaners have a brace fastened by screws. When removing a cleaner, hold it level so you do not spill the oil (on oil-bath type). Take off the cleaner wing nut and cap so the filter element can be removed. Wash the filter element thoroughly in clean gasoline or cleaning fluid. After it has dried, dip it in clean engine oil and set it aside to drain. Then, on the oil-bath type of cleaner, drain the old oil and wash the cleaner. Scrape off caked dirt. Fill the oil reservoir to the oil-level mark with oil of the specified grade. Install the filter element and replace the cap. When reinstalling the cleaner, hold it level so you do not spill the oil.

§150. Manual-choke adjustment On manual chokes, a choke button on the dash is linked through a control wire in a conduit to the choke valve in the carburetor (Fig. 9-2). If the wire slips in the screw clamp or if it kinks, the choke valve may not open and close properly as the choke control is moved in and out. It is a simple operation to loosen the screw clamp and slide the wire one way or the other to get proper adjustment. With the choke button in, the choke valve should be open. With the choke button pulled out, the choke valve should be closed. Kinks may be straightened by bending the wire. Sometimes the conduit supports are bent out of line, causing the wire to bind inside the conduit. The supports should be straightened. If the wire still binds, put a few drops of penetrating oil along the conduit. It will penetrate to the wire and lubricate it.

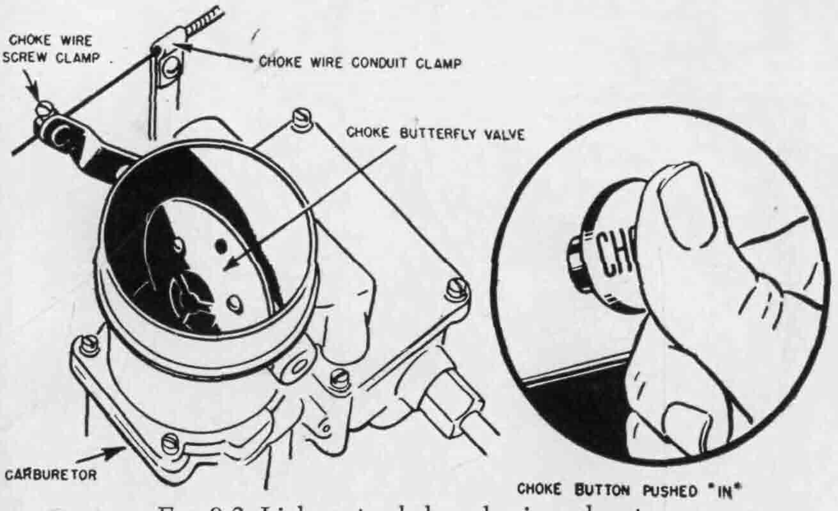


FIG. 9-2. Linkage to choke valve in carburetor.

§151. Automatic-choke adjustment Automatic chokes, or climatic controls, are of two general types. One type, electrically operated, is mounted on the exhaust manifold and is linked by a rod to the carburetor choke valve (Fig. 9-3). Other types are mounted on the carburetor (Fig. 9-4). See also §72 for other illustrations of automatic chokes.

1. *Electric choke.* To adjust the type of choke shown in Fig. 9-3, remove the air cleaner and open the throttle enough to release the

fast-idle cam. Then close the choke valve by hand, or pull on the control rod until the hole in the choke control shaft and the notch in the choke control base align. Insert the adjusting tool as shown to hold the control in this position. Now, loosen the clamp screw on the choke lever, and move the lever until the choke valve is tightly closed. Hold the choke valve closed, and tighten the clamp screw.

2. *Hot-air choke.* To adjust the type of choke shown in Figs.

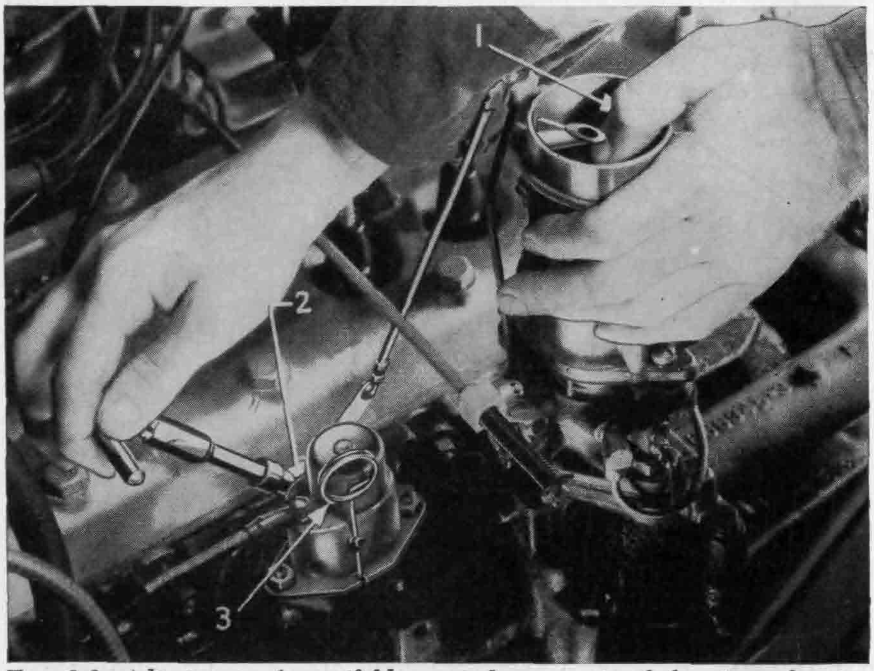


FIG. 9-3. Adjustment of manifold-mounted automatic choke. 1, carburetor choke valve; 2, choke-lever clamp screw; 3, adjusting tool. (*Chrysler Sales Division of Chrysler Corporation*)

4-20 or 9-4, loosen the two or three cover clamp screws and turn the cover one way or the other to obtain a richer or leaner warm-up mixture. On the type of choke shown in Fig. 9-4, the heat-tube coupling must be loosened before the adjustment is made. Adjustment should be made one notch at a time. When adjustment is correct, the choke valve should move to the fully opened position as the engine warms up and reaches operating temperature. With the adjustment complete, tighten the clamp screws and, on the choke shown in Fig. 9-4, tighten the heat-tube coupling.

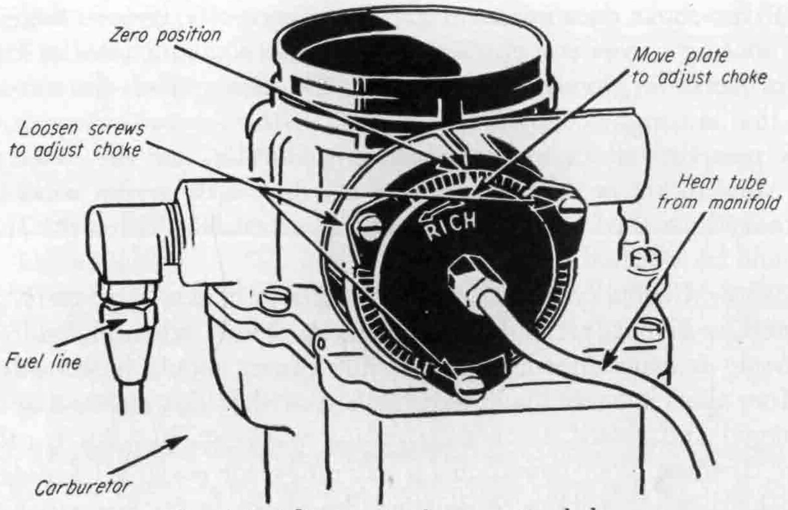


FIG. 9-4. Adjustment of automatic choke.

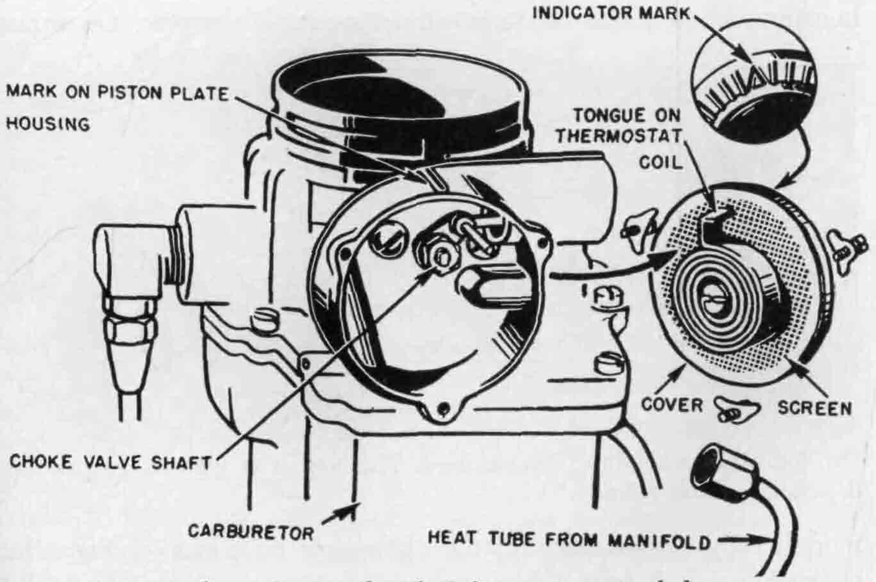


FIG. 9-5. Heat tube and cover detached from automatic choke so screen can be seen.

from a hammer blow might set off vapor remaining in the tank with a terrific explosion.

The fuel filter in the tank (where present) can be cleaned, if the tank is removed, by blowing air through it from an air hose. Air should be directed through the filter from the fuel outlet.

When replacing a tank, make sure that the supports are firmly fastened. Also clean the fuel-gauge terminals well so that good contact will be made when the wires are connected.

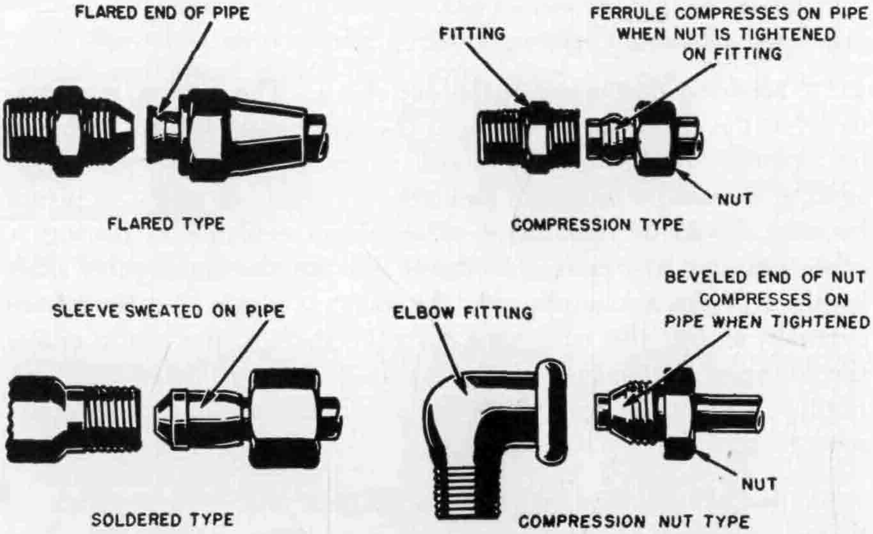


FIG. 9-7. Various types of fuel-line couplings or fittings.

§155. Fuel lines Fuel lines (or pipes, or tubes, as they are also called) are attached to each other and to the carburetor, fuel pump, and tank by means of different types of coupling (Fig. 9-7). When loosening a coupling of the type having two nuts, use two wrenches as shown in Fig. 9-8 in order to avoid twisting the line and possibly damaging it.

When installing a new line of the flared type, it is best to double-flare the tube as shown in Figs. 9-9 and 9-10. This double flaring assures a safer and tighter connection. One type of tool used to double-flare tubes is shown in Fig. 9-11. The tube is first cut off square and the cuttings cleaned out of the tube. Then the tube is inserted into the tool the proper depth, and the "first-flare" forming tool is driven against the tube to form it as shown in Fig. 9-9. Next the other forming tool is used to drive the flare on down so that the double flare is formed, as shown in Fig. 9-10.

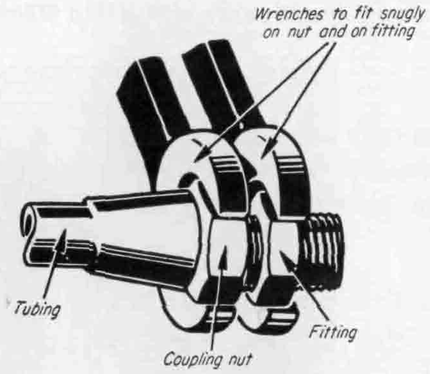


FIG. 9-8. Method of using two wrenches to loosen or tighten coupling nuts and thereby avoid twisting and damaging the line.

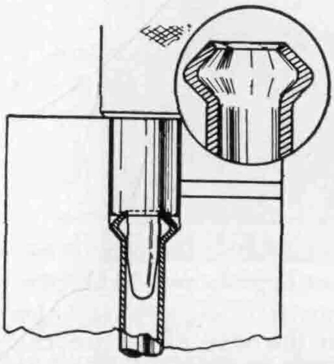


FIG. 9-9. Making the first flare. (*Kent-Moore Organization, Inc.*)

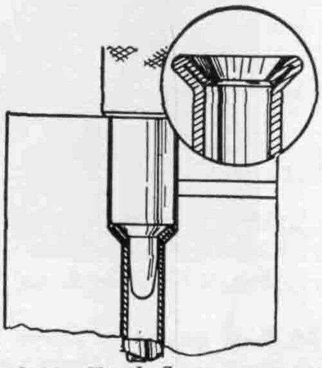


FIG. 9-10. Final flaring operation. (*Kent-Moore Organization, Inc.*)

Fuel lines should be adequately supported at various points along the frame. If a line is rubbing against a sharp corner, it should be moved slightly to avoid wear and a possible leak. Fuel lines must not be kinked or bent unnecessarily since this treatment is apt to cause a crack and a leak.

If the fuel line between the pump and tank is thought to be clogged, it may be tested by disconnecting the line at the pump and applying an air hose to it. Remove the tank filler cap. Do not apply too much air since this might blow gasoline out of the tank.

If the line will not pass air freely, it could be clogged with dirt; or perhaps it has become badly kinked or pinched at a bend or support. Also, on tanks with an internal filter, the filter may have become clogged, although this is extremely rare. Kinked or pinched lines should be replaced since the kinked or pinched place, even if straightened, may ultimately crack open and leak.

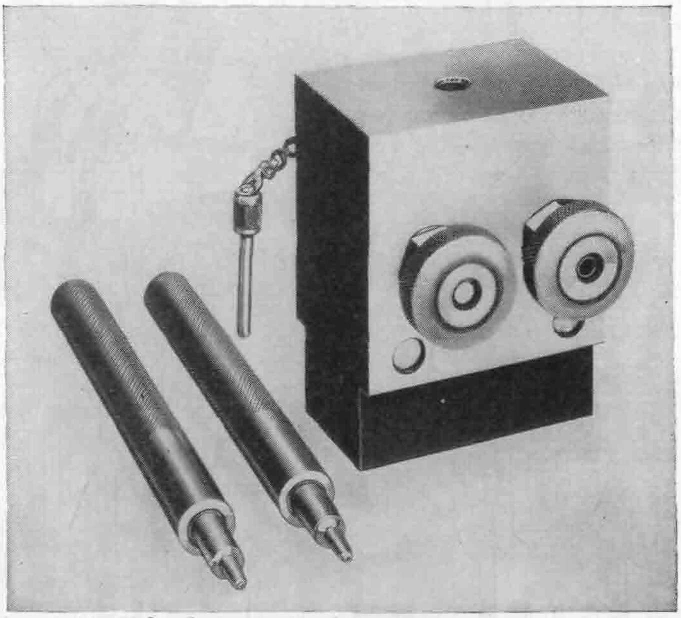


FIG. 9-11. Tube-flaring tool. (*Kent-Moore Organization, Inc.*)

§156. Fuel gauges There is very little in the way of service that fuel gauges require. Defects in either the dash unit or the tank unit usually require replacement of the defective unit. However, on the type of gauge that makes use of vibrating thermostatic blades (§38), dirty contact points, which may cause fluctuations of the needle can be cleaned by pulling a strip of clean bond paper between them. Be sure that no particles of paper are left between the points. Never use emery cloth to clean the points since particles of emery will embed in the points and cause very erratic gauge action.

If a fuel gauge is defective or malfunctioning of the gauge is suspected, substitute a new tank unit for the old one. This can be done without removing the old tank unit, by disconnecting the tank-unit terminal lead from the old unit and connecting it to the terminal of the substitute unit. Then connect a lead from the frame of the substitute unit to any convenient grounding place on the car in order to assure good grounding of the unit. With these connections made, turn on the ignition switch and operate the float arm of the substitute unit. If the dash unit now works and indicates as the float arm is moved up and down, then the old tank unit is defective. If the dash unit still does not work, then either it is at fault or else the wiring is defective.

NOTE: On the thermostatic type of fuel gauge, it takes a minute or so for the thermostats to heat up and start the dash unit indicating. Therefore, on these, wait for a minute or so after turning on the ignition switch.

CHECK YOUR PROGRESS

Progress Quiz 7

Here is your chance to check up on the progress you have been making since you started Chap. 9. The questions below will help you review the material you have just covered and will also fix the more important points more firmly in your mind. If any of the questions stump you, reread the pages that will give you the answer.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. When servicing an air cleaner, the filter element should be *replaced* *washed in oil* *washed in cleaning fluid*
2. In the manual choke, when the choke button on the dash is pulled all the way out, the choke valve should be *closed* *nearly closed* *open*
3. To adjust the hot-air choke to get a richer or leaner warm-up mixture, the *control wire must be adjusted* *cover must be turned* *adjusting screw must be turned*
4. Generally speaking, the automatic choke, if properly adjusted to start with, *will require adjustment once a month* *will require adjustment once a year* *will not get out of adjustment*
5. Automatic chokes *should be lubricated monthly* *should be lubricated yearly* *should be lubricated with light oil* *do not require lubrication*

6. A fuel line that is kinked or pinched should be *straightened by hand* *replaced* *straightened with light hammer blows*
7. As a general rule, a defective fuel-guage unit *can be readjusted* *can be rewired* *should be replaced*
8. Location of trouble in a fuel-gauge system can usually be determined by temporarily substituting *a new tank unit* *a new dash unit* *new wiring*

§157. Fuel-pump inspection The fuel pump can be checked for pressure, capacity, or vacuum with special gauges as already explained (§§129 to 131). The vacuum pump of the combination pump can also be tested with the vacuum gauge. Readings obtained should be compared with the specifications issued by the manufacturer for the model of pump being tested. A rather rough test of fuel-pump action can be made by loosening or disconnecting the fuel line from the carburetor and then cranking the engine. Ignition should be off or the lead from the ignition coil high-tension terminal grounded so that the engine does not start. During cranking, the fuel pump should deliver a spurt of gasoline with each rotation of the engine camshaft. Have a container ready to catch the gasoline, and wipe up any spilled gasoline with cloths and put the cloths outside to dry.

In addition to checks of the operating action, the fuel pump should be checked for leaks. Leaks might occur at fuel-line connections or around sealing gaskets, as, for instance, at the joint between the sediment bowl and the cover or at the joint between the cover and the pump body.

1. Vacuum-pump test. As mentioned above, vacuum-pump action can be checked with the vacuum gauge. With the vacuum gauge connected to the vacuum side of the pump, the vacuum developed should be within the specifications of the manufacturer. A quick check of the vacuum-pump action can be made by turning on the windshield wipers with the engine running and then accelerating the engine quickly. If the windshield wipers continue to operate at about the same speed, the vacuum pump is probably all right. However, if the wipers slow down considerably or stop when the engine is accelerated, the vacuum-pump diaphragm is probably cracked or broken. This is a bad situation, not so much from the standpoint of windshield-wiper failure during acceleration, but because oil can pass through the crack and into the engine combustion chambers. This, in turn, produces excessive oil consumption and all the engine ailments associated with it (see §227).

NOTE: Windshield wipers will not work as well on dry windshields as on wet windshields. Throw water on the windshield if you want to see how the wipers will perform under actual driving conditions.

2. *Cleaning sediment bowl.* The sediment bowl should be checked for accumulated water and dirt. Water and dirt should be flushed out by removing the bowl. The bowl is removed by loosening the nut on the bailing wire and pulling the wire to one side. While the bowl is off, the filter screen can also be cleaned with cleaning fluid and compressed air. When the bowl is replaced, the nut should be pulled up tightly so that leakage cannot occur around the bowl gasket. If the gasket is at all damaged, a new gasket should be used.

3. *Conditions requiring pump removal.* If the fuel pump pressure is too high or too low, if the pump does not deliver fuel normally to the carburetor, if leaks show up, if the pump has a cracked diaphragm or other defect, or if the pump is noisy, then the pump should be removed for repair as explained in following sections. The following section describes various pump troubles and their causes.

§158. Fuel-pump troubles The trouble-shooting chart in Chap. 8 lists various fuel-system troubles and their causes. Some of these causes may lie in the fuel pump; many of them are in the other fuel-system or engine components. Fuel-system troubles that might be caused by the fuel pump are discussed below.

1. *Insufficient fuel delivery.* This could result from low pump pressure, which in turn could be due to any of the following:

a. Broken, worn-out, or cracked diaphragm.
b. Improperly operating fuel-pump valves.
c. Broken diaphragm spring.
d. Broken or damaged rocker arm.
e. Clogged pump-filter screen.
f. Air leaks into sediment bowl due to loose bowl or worn gasket.

In addition to these causes of insufficient fuel delivery due to conditions within the pump, many other conditions outside the pump could prevent delivery of normal amounts of fuel. These are listed and described in detail in Chap. 8 and include such things as a clogged fuel-tank-cap vent, clogged fuel line or filter, air leaks into the fuel line, and vapor lock. Of course, in the carburetor, an incorrect float level, clogged inlet screen, or malfunctioning inlet needle valve would prevent delivery of adequate amounts of fuel to the carburetor.

2. *Excessive pump pressure.* High pump pressure will cause delivery of too much fuel to the carburetor since the excessive pressure will tend to lift the needle valve off its seat so that the fuel level in the float bowl will be too high. This results in an overrich mixture and excessive fuel consumption. Usually, high pump pressure would result only after a fuel pump has been removed, repaired, and replaced. If a fuel pump has been operating satisfactorily, it is hardly likely that its pressure would increase enough to cause trouble. High pressure could come from installation of an excessively strong diaphragm spring or from incorrect reinstallation of the diaphragm. If the diaphragm is not flexed properly when the cover and housing are reattached, it will have too much tension and will produce too much pressure. There is more on this point in the fuel-pump reassembly procedures that follow.

3. *Fuel-pump leaks.* The fuel pump will leak fuel from any point where screws have not been properly tightened and also where the gasket is damaged or incorrectly installed. If tightening screws does not stop the leak, then the gasket or diaphragm will require replacement. Note also that leaks may occur at fuel-line connections which are loose or improperly coupled.

4. *Fuel-pump noises.* A noisy pump is usually the result of worn or broken parts within the pump. These include a weak or broken rocker-arm spring, worn or broken rocker-arm pin or rocker arm, or a broken diaphragm spring. In addition, a loose fuel pump or a scored rocker arm or cam on the camshaft may cause noise. Fuel-pump noise may sound something like engine-valve tappet noise since its frequency is the same as camshaft speed. If the noise is bad enough, it can actually be "felt" by gripping the fuel pump firmly in the hand. Also, careful listening will usually disclose that the noise is originating in the vicinity of the fuel pump. Tappet noise is usually distributed along the engine, or is located more distinctly in the valve compartment of the engine.

§159. Fuel-pump removal As a first step in removing the fuel pump, wipe off any dirt or accumulated grease so that dirt will not get into the engine. Then take off heat shield (where present), and disconnect the fuel lines (Fig. 9-8) and vacuum-pump lines (on combination pump). Remove attaching nuts or bolts, and lift off pump. If it sticks, work it gently from side to side, or pry lightly under the mounting flange with a screw driver to loosen it. Do not damage the flange or attaching studs. On engines using a push rod to operate the fuel pump, remove the rod so that it can be examined for wear or sticking.

§160. Fuel-pump disassembly and assembly Many automotive service departments do not attempt to disassemble and repair fuel pumps because pump manufacturers have arranged a special pump-exchange program. The old pumps can be traded in on new or factory rebuilt units. For those who prefer to repair fuel pumps, special repair kits are supplied. These repair kits contain diaphragms, valves, springs, and gaskets. For combination pumps, three separate repair kits may be provided: a vacuum-pump diaphragm kit, a fuel-pump diaphragm kit, and an overhaul kit. The vacuum-pump diaphragm and fuel-pump diaphragm kits contain only the diaphragm, valves, springs, and gaskets needed to repair the vacuum or the fuel pump. The overhaul kit includes everything in both kits plus links and other parts that might wear. Thus, it can be seen that repair of a fuel pump may require replacement of nearly all the parts in it. Figure 9-12 shows an overhaul kit for a combination pump.

Disassembly procedures for fuel pumps vary somewhat according to their construction. Generally speaking, there are two types of pumps, the fuel pump and the combination fuel and vacuum pump; thus there are two general disassembly procedures. Regardless of the procedure, the first step is to clean the outside of the pump thoroughly to remove all dirt, grease, or oil. A simple way of doing this is to plug the pump openings, wash the outside of the pump in cleaning solvent, and then blow it dry with an air hose. Next the fuel body and cover or covers should be lightly scratched with a sharp knife or file so that their original relationship is established. These marks should be realigned on reassembly. After this, the disassembly procedure may begin.

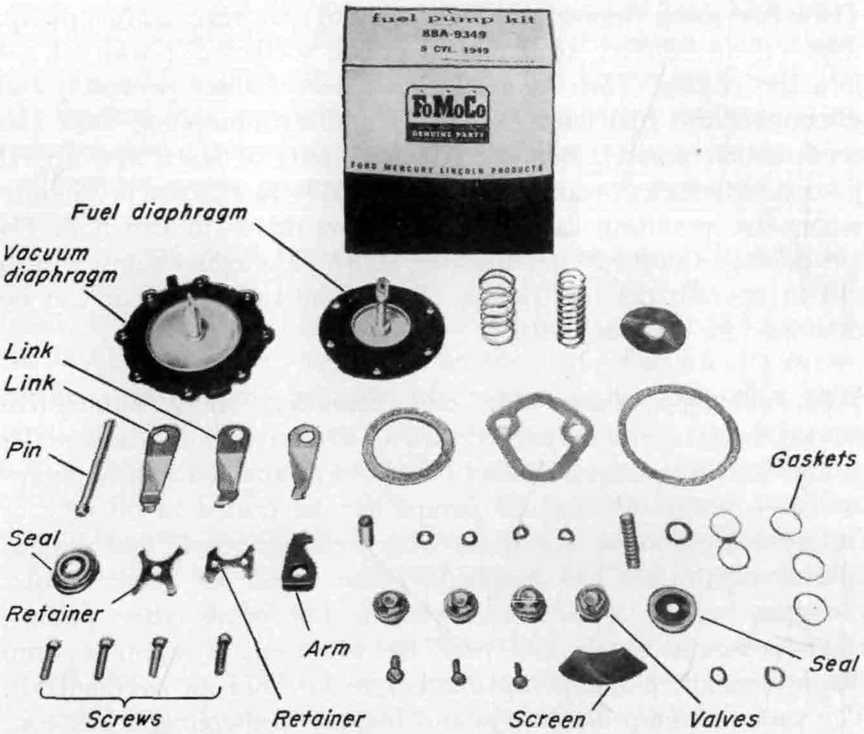


FIG. 9-12. Repair kit for a combination fuel and vacuum pump. (*Ford Motor Company*)

§161. Fuel-pump disassembly and reassembly, type 1 Figure 9-13 is a sectional view and Fig. 9-14 a disassembled view of one type of fuel pump which may have either a glass or a metal sediment bowl. Disassembly is as follows:

1. Take off sediment bowl and strainer.
2. Remove cover screws and lock washers so body and cover can be separated. Do not pry between flanges with a screw driver if parts stick, as this would damage the sealing faces. Instead, tap them apart with the handle of a screw driver or a plastic hammer.
3. Take out valve-retainer screw, and remove retainer and valves. Note carefully the locations of the valves so that they may be returned to their proper ports.
4. Push in on center of diaphragm so the diaphragm stem can be unlinked from the inner rocker-arm link.
5. Drive out rocker-arm pin if it is necessary to remove the rocker arm.

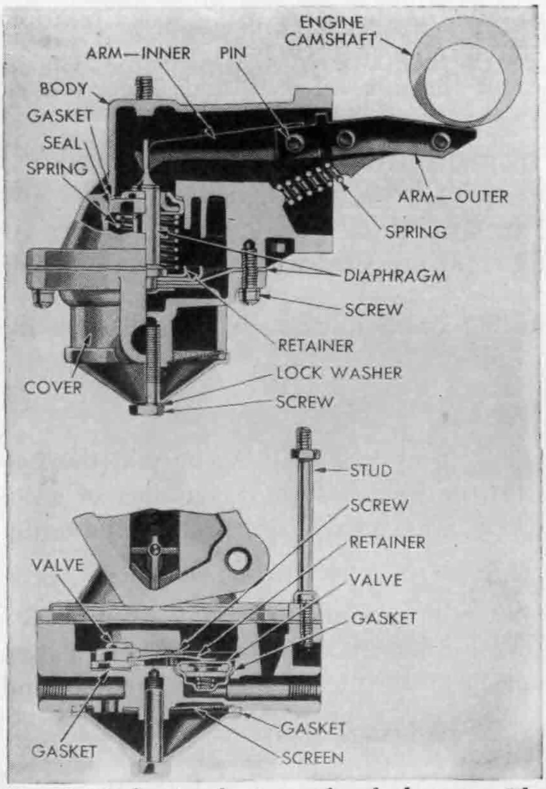


FIG. 9-13. Sectional views of a fuel pump. The different sectional views were made to show the diaphragm (top) and the valves (bottom). (*Plymouth Division of Chrysler Corporation*)

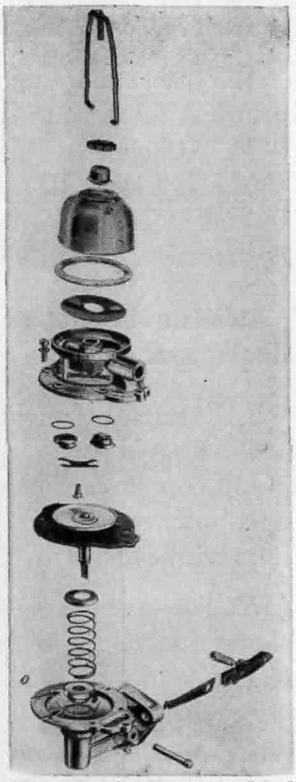


FIG. 9-14. Disassembled view of fuel pump in Fig. 9-13. (*Plymouth Division of Chrysler Corporation*)

6. If the oil seal (which fits around the diaphragm stem) is damaged, it may be removed from the body by chipping off the pieces of the housing holding it in place and then driving it out. The new oil seal should be staked to the housing with a hammer and diamond-point chisel.

7. After disassembly, all parts should be washed in kerosene or gasoline. Any damaged parts should be discarded and new parts used on reassembly. Usually this means obtaining an overhaul kit.

8. Reassembly is practically the reverse of disassembly. All parts must be clean, and the new diaphragm should be soaked in kerosene or gasoline.

9. Valves should be installed in the cover in the exact positions as on the original unit. Tighten retainer screw.

10. Insert diaphragm stem through oil seal, and insert rocker-arm link into slot in stem.

11. Attach cover and diaphragm to body with screws and lock washers. Leave all screws quite loose, and then hold rocker arm to end of its stroke tight against spring pressure while screws are tightened. This seats diaphragm properly with the correct flexing.

Caution: Do not use sealing compounds such as shellac on the diaphragm.

12. Attach sediment chamber.

13. Rough-test the pump by connecting rubber hose at the two pump couplings. Then insert the inlet hose in a container of gasoline, and work the rocker arm. Fuel should spurt out of the outlet hose with every stroke of the arm.

§162. Fuel-pump disassembly and reassemby, type 2 Figure 3-7 shows a second type of fuel pump which is similar to the one shown in Fig. 9-13 but which requires a slightly different disassembly and assembly procedure.

1. Take off sediment bowl and screen.

2. Remove top cover screws and cover. Do not pry the cover off if it sticks, since this would damage the sealing faces. Instead, tap the cover off with a plastic hammer or the handle of a screw driver.

3. Raise the edge of the diaphragm so that a thin-bladed screw driver can be inserted. With the screw driver, lift the spring body and oil seal off the boss in the fuel-pump body, and slide it to one side.

4. Unhook the diaphragm stem from the rocker-arm link by pressing down on the diaphragm and tilting it away from the rocker arm.

5. Remove oil seal and retainer from diaphragm stem.

6. Remove valve retainers and valves. Note positions of valves carefully so that valves can be restored to original positions.

7. Wash all parts in cleaning solvent, and discard defective parts. Use overhaul kit with new parts in it. Soak new diaphragm in gasoline before installing it.

8. Assemble oil seal on diaphragm stem. Put oil-seal spring on first, followed by upper retainer, two leather seals, and lower retainer with convex part, or cup, out.

9. Raise the rocker-arm link with a screw driver as shown in Fig. 9-15, and, with the diaphragm spring in place, hook the link into the diaphragm stem. Then slide the diaphragm and seal assembly over until the seal drops down over the boss on the body.

10. Install valves with retainer and gaskets.

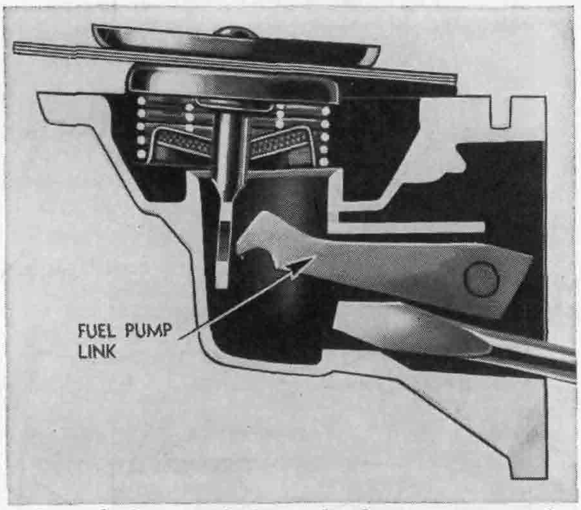


FIG. 9-15. Hooking fuel-pump link to diaphragm stem with screw driver. (*Chevrolet Motor Division of General Motors Corporation*)

11. Attach the cover and body with screws and lock washers, making sure that the diaphragm is seated and flexed while the screws are tightened.

12. Attach screen and sediment bowl.

13. Test as noted in §161, 13.

§163. Combination fuel- and vacuum-pump disassembly and reassembly, type 1 Figure 9-16 is a sectional view of one type of combination fuel and vacuum pump which has the fuel pump above and the vacuum pump below. Figure 9-17 is a disassembled view of a similar unit. Both the vacuum and the fuel pumps operate from the same rocker arm. Disassembly and reassembly procedures follow.

1. To disassemble the fuel pump, first take off the sediment bowl and screen.

2. Take out cover attaching screws and lock washers, and lift off cover.

3. Note positions of valves, and then remove retainer screw, retainer, and valves.

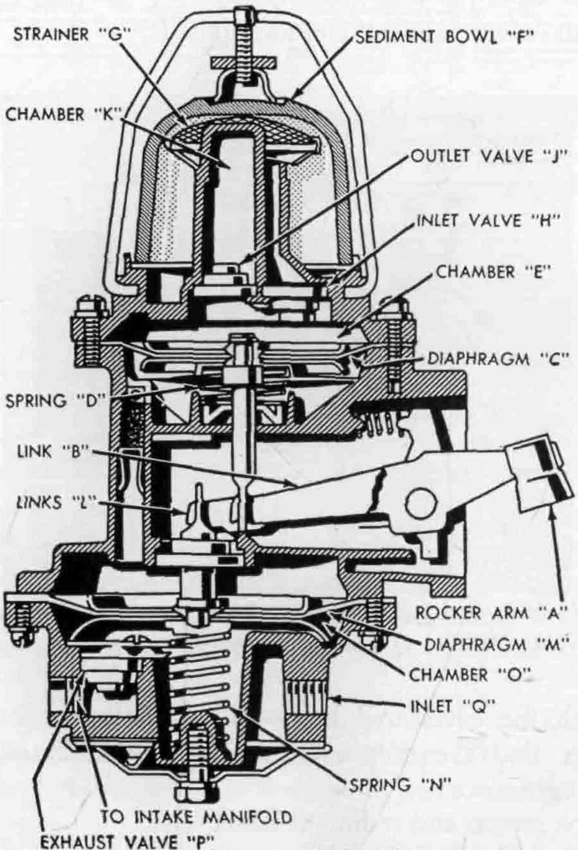


FIG. 9-16. Sectional view of combination fuel and vacuum pump. (*Ford Motor Company*)

4. Press diaphragm down at center and tilt it to one side, away from rocker arm, so that rocker-arm link can be withdrawn from slot in diaphragm stem.

5. Take off diaphragm with oil-seal parts (including spring, washers and retainers).

6. To disassemble the vacuum pump, take out two cover screws

and substitute two long screws for them, turning the long screws all the way in. Then take out the other screws. Now, loosen the two long screws little by little to relieve the vacuum-pump spring pressure. When the pressure is relieved, take out the screws and take off the cover.

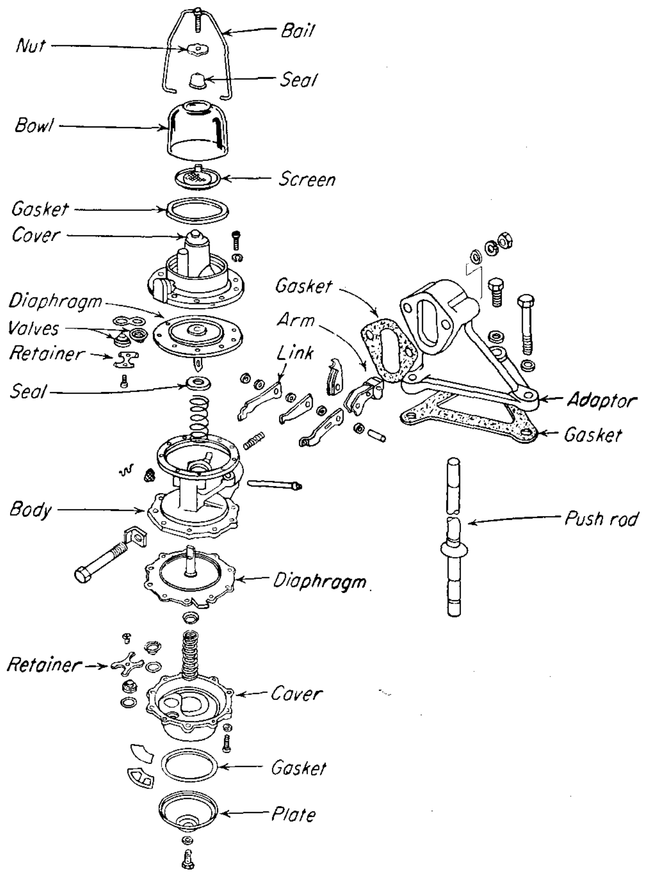


FIG. 9-17. Disassembled view of combination fuel and vacuum pump. (*Ford Motor Company*)

7. Remove valves by taking off retainer. Note positions of valves so they can be replaced in proper positions.

8. Unlink diaphragm stem from rocker-arm link.

9. Replace oil seal through which vacuum-pump diaphragm stem moves, if it is defective.

10. Wash all parts in cleaning solvent, and discard defective

parts. Use overhaul kit with new parts for reassembly. Soak new diaphragms in gasoline before installing them.

11. To reassemble vacuum pump, install valves and retainer. Put vacuum-pump diaphragm on body, and link diaphragm stem to rocker-arm link. Then put diaphragm spring in place, and use two long screws to compress spring and bring vacuum-pump cover into position on body. Install attaching screws and lock washers, and then remove long screws so that the last two attaching screws can be put into place.

12. Reassemble the fuel pump by installing valves and retainer. Put oil-seal parts on diaphragm stem, and place diaphragm on pump body. Attach link to diaphragm stem, and then attach fuel-pump cover to body with screws. Have diaphragm flexed when screws are tightened in order to make sure that the diaphragm is not creased and will not have excessive tension.

13. Test fuel pump as in §161, 13. Vacuum pump cannot be tested with pump off the car without special equipment, but it can be tested after installation as explained in §157.

§164. Combination fuel- and vacuum-pump disassembly and reassembly, type 2 Figures 9-18 and 9-19 are disassembled views of combination pumps which have the fuel pump below and the vacuum pump above. Both fuel and vacuum pumps operate from the same rocker arm. Disassembly and reassembly procedures follow.

1. Remove vacuum cover by taking out two screws and substituting two long screws for them. Turn these screws in tight. Then take out other cover screws, and gradually back off long screws to relieve diaphragm-spring tension slowly. Then turn pump so that vacuum diaphragm is down, and push up on diaphragm, tilting diaphragm stem to one side so that the rocker-arm link is unlinked from the stem. Take off diaphragm, and remove oil-seal spring, seal, and retainers from stem.

2. Remove valves from vacuum-pump cover after noting their positions.

3. Remove fuel cover by taking out attaching screws and lock washers. Take valves out of cover after noting their positions. To remove the diaphragm, it must be detached from the rocker-arm link, and the best way to do this without damaging the oil seal is

to drive out the rocker-arm pin with a punch and hammer. Then the link may be detached from the diaphragm stem.

4. Remove the diaphragm by drawing it *straight* out of the oil seal. Tilting it is apt to damage the seal, and this would require installation of a new seal.

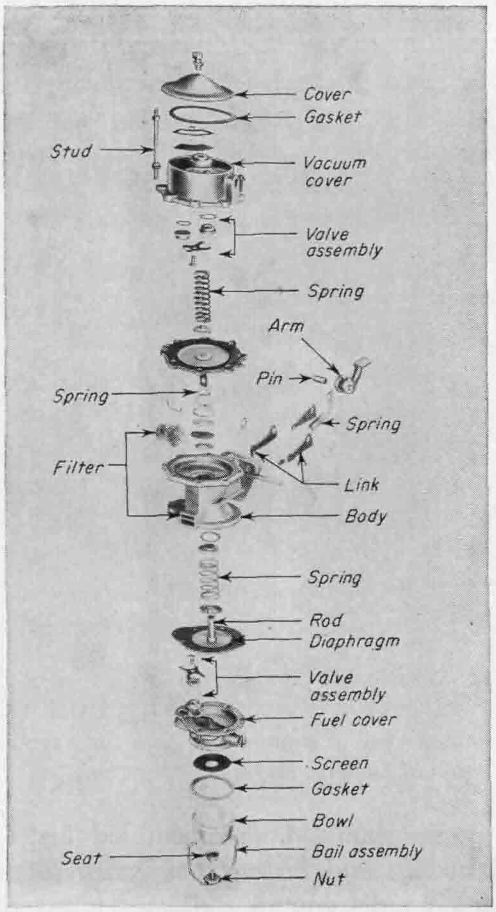


FIG. 9-18. Disassembled view of combination fuel and vacuum pump. (*Plymouth Division of Chrysler Corporation*)

5. A new oil seal should be installed if the old one is damaged. The old one can be removed with a driver or special puller. The new one is then installed and snugged, or staked, into place with a special tool.

6. After all parts are removed, they should be cleaned in clean-

ing solvent, and defective parts should be discarded. An overhaul kit will supply the new parts. Soak new diaphragm in gasoline or kerosene before installation.

NOTE: On some models the overhaul kit includes a fuel diaphragm gasket to compensate for any slight warpage of the fuel cover and assure a tight joint between the cover and body.

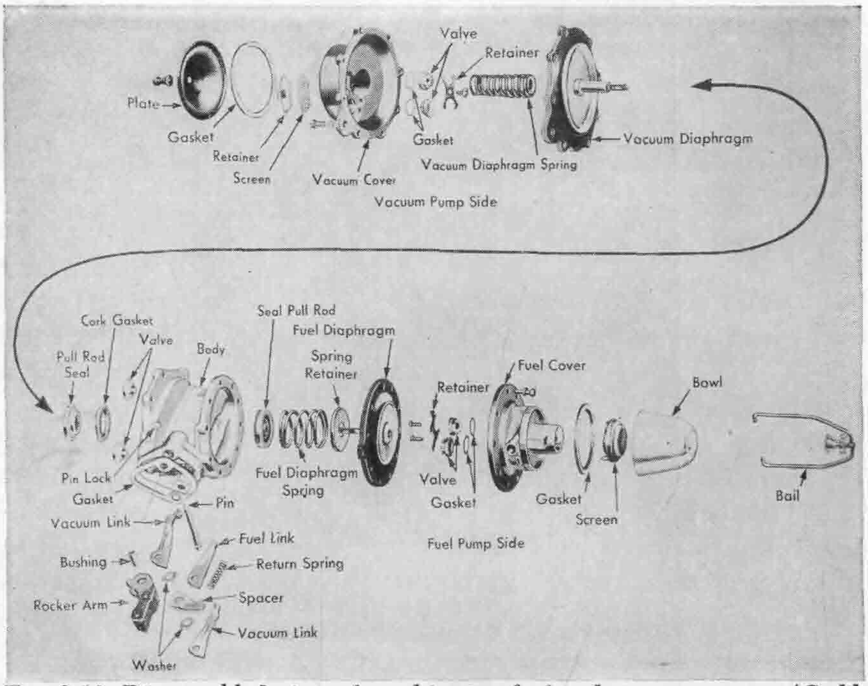


FIG. 9-19. Disassembled view of combination fuel and vacuum pump. (*Cadillac Motor Car Division of General Motors Corporation*)

7. The fuel pump should be reassembled first. Put valves in cover (or fuel body), and fasten them with retainer. Place retainer and spring on diaphragm rod, and insert diaphragm rod straight into oil seal in body. A special tool may then be necessary to attach link to the diaphragm stem, after which the rocker-arm assembly can be attached with the arm pin. The end of the pin should be peened over to prevent its loosening.

8. With the diaphragm in place, attach the fuel cover to the body with screws and lock washers. Run the screws up loosely, and then make sure that the diaphragm is centered and fully

flexed. Then tighten the screws. Do not tilt diaphragm during reassembly as this might damage the oil seal.

9. Assemble the vacuum pump by installing the valves with retainer. Then put diaphragm, with oil-seal parts, in place on body, and tilt it so that rocker-arm link can slip into slot in diaphragm stem. Put spring in place, and attach cover with two long screws, running the screws down evenly to draw cover down and compress spring. Install other screws, remove two long screws, and put regular screws in their place.

10. Test fuel pump as in §161, 13. Vacuum pump cannot be tested off the engine without special equipment, but it can be tested after installation as explained in §157.

§165. Fuel-pump installation Make sure that the fuel-line connections are clean and in good condition. Connect the fuel and vacuum lines to the pump before attaching the pump to the engine. Then place a new gasket on the studs of the fuel-pump mounting or over the opening in the crankcase. The mounting surface of the engine should be clean. Insert the rocker arm of the fuel pump into the opening, making sure that the arm goes on the proper side of the camshaft (or that it is centered over the push rod). If it is hard to get the holes in the fuel-pump flange to align with the holes in the crankcase, turn the engine over until the low side of the camshaft eccentric is under the fuel-pump rocker arm. Now the pump can be installed without forcing or prying it into place. Attach with bolts or nuts. Check pump operation as explained in §157.

CHECK YOUR PROGRESS

Progress Quiz 8

Once again you can check your progress in the book. The following quiz covers fuel-pump servicing procedures as described in the second half of the chapter. The questions will serve as a review of the important points covered in the chapter and will help you to remember them.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. To quick-check the fuel-pump action, loosen or disconnect fuel line from carburetor *with engine running at medium speed* *with engine idling* *and then crank the engine*
2. If the vacuum-pump diaphragm is cracked or broken, accelerating the engine quickly will cause the windshield wipers to *speed up* *stop* *slow down very little*
3. A cracked vacuum-pump diaphragm will allow oil to pass through the crack and cause *an oily windshield* *excessive oil consumption* *excessively fast wiper action*
4. A broken diaphragm or spring, stuck valves, clogged screen, or air leaks in the fuel pump can cause *high pump pressure* *low pump pressure* *high float level* *rich mixture*
5. A high fuel level in the float bowl and an excessively rich mixture could result from *low pump pressure* *high pump pressure* *a cracked diaphragm*

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You are now well into the part of the book that gives you practical guidance in actual shopwork on automotive fuel systems. Sample servicing procedures on the various fuel-system components are covered on these pages. You should have a good idea of how to service these components, and for this reason step-by-step procedures on several models of components are included. As you study these procedures, you will learn the important details of fuel-system service. The following chapter review test gives you a chance to find out how well you have remembered the essential points covered in the chapter.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. To prevent loss of air-cleaner efficiency, the filter element must be removed from the cleaner periodically and *thrown away* *cleaned* *blown out with compressed air*
2. With the adjusting tool holding the electric choke control in position, the choke valve should be *tightly closed* *wide open* *half open*
3. To adjust the hot-air choke, loosen the two or three cover clamp screws and turn the *clamp* *carburetor* *choke valve* *cover*

4. If a fuel tank is to be repaired, great care must be used to make sure it is absolutely free of *water vapor* *attaching studs* *gasoline vapor* *fuel-gauge wires*
5. Double flaring the fuel-line tube assures *shorter tubing* *a safer and tighter connection* *stiffer tubing* *longer tubing*
6. To locate trouble in a fuel-gauge system, temporarily substitute for the old unit a *new dash unit* *new wire* *new tank unit* *new switch*
7. A quick check of vacuum-pump action can be made by turning on the windshield wipers and then *stopping the engine* *starting the engine* *accelerating the engine* *turning off the wipers*
8. A broken fuel-pump diaphragm spring, improperly operating pump valves, broken diaphragm, clogged screen, or air leaks could cause *high fuel-pump pressure* *fuel-tank stoppage* *insufficient fuel delivery to carburetor*
9. An excessively strong fuel-pump diaphragm spring or an improperly installed diaphragm could cause *insufficient fuel delivery* *high pump pressure* *fuel-gauge reading* *loose connections*
10. Before they are installed, new diaphragms should be *hot* *soaked in gasoline* *stretched* *cold*

Service Procedures

In the following, you should write down in your notebook the procedures asked for. Do not copy the procedures from the book, but try to write them in your own words. Give a step-by-step account of how to do the service job asked for. This will help you remember the procedures later when you go into the automotive shop. If possible, get hold of various fuel pumps and instruction manuals on fuel pumps. Study them, and base your write-ups on them instead of those covered in the book. This will give you a wider experience in fuel pumps.

1. Explain how to adjust a manual choke.
2. Explain how to adjust an electric choke.
3. Explain how to adjust a hot-air choke.
4. Explain how to remove and replace a hot-air choke.
5. Explain how to remove and replace a fuel line.
6. Explain how to check a defective fuel-gauge system.
7. Explain how to check a fuel pump for pressure, capacity, and vacuum.
8. Explain how to quick-check a fuel pump.
9. Explain how to check a vacuum pump by using the windshield wipers.

10. List conditions that would require fuel-pump removal.
11. List conditions in the fuel pump that could cause insufficient fuel delivery.
12. List conditions outside the fuel pump that could cause insufficient fuel delivery.
13. List causes of excessive fuel-pump pressure.
14. Explain how to remove a fuel pump from an engine.
15. Explain how to disassemble and reassemble a fuel pump.
16. Explain how to disassemble and reassemble a combination fuel and vacuum pump.
17. Explain how to install a fuel pump on an engine.

SUGGESTIONS FOR FURTHER STUDY

When you are in the automotive shop, keep your eyes and ears open so that you can learn more about how the various fuel-system jobs are done. Study any carburetor and fuel-pump manuals you can lay your hands on. Carefully examine any carburetors and fuel pumps you can. If the shop has some old or defective units, perhaps you can borrow them so that you can practice disassembling and reassembling them. The more practice you can get in handling the small parts that go into these units, the better. If you can find particular model fuel pumps and the fuel-pump manuals that apply to them, study the manuals carefully and then follow the step-by-step procedures in disassembling and reassembling the pumps. Write down in your notebook any important points, or even whole procedures, on these service operations. You will find that writing these facts down will help you remember them. At the same time, you will find that your notebook is becoming an increasingly valuable reference for you.

10: Carburetor service

THIS CHAPTER continues the discussion of fuel-system service and covers the disassembly, repair, reassembly, and adjustment of carburetors. Carburetor service requires a number of special tools, and their use is described on following pages where the servicing jobs are covered. In addition, several common hand tools are needed. These common hand tools are described in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*). Refer to that book for information on them.

§166. Cleanliness It is extremely important to keep carburetor parts and circuits as clean as possible. Bits of dirt or dust that are allowed to get into the carburetor will probably cause carburetor and engine trouble sooner or later. The jets or nozzles and circuits through which gasoline flows are carefully calibrated to within thousandths of an inch. Dirt or gum that changes this calibration will have a marked effect on carburetor and engine performance. On the other hand, careless cleaning of the nozzles or jets may enlarge them slightly, resulting in overrichness, fuel waste, and excessive carbon in the engine with all its attendant ills.

The two general cautions about use of the air hose, and the explosiveness of gasoline vapor, contained at the end of §148, also apply in regard to carburetor service. Reread those cautions now. Heed them at all times when working in the automotive shop.

§167. Carburetor troubles Various carburetor troubles are outlined in detail in Chap. 8; the trouble-shooting chart lists the various causes of the different complaints that might arise from malfunctioning of the carburetor or other fuel-system component. In the carburetor, such conditions as incorrect fuel level in the float bowl, incorrect idle-speed and idle-mixture adjustments, clogged idle or high-speed circuit, or malfunctioning accelerator-pump system can cause trouble. Quick checks of these various circuits are outlined in §147.

Various engine troubles that can be caused by the carburetor are listed below. Remember that many other conditions outside the carburetor can also cause these troubles. See the trouble-shooting chart in Chap. 8 and also the more comprehensive engine trouble-shooting chart in the *Automotive Engines* book for more complete information on this matter.

1. Excessive fuel consumption can result from a high float level or a leaky float, sticking or dirty float needle valve, worn jets or nozzles, stuck metering rod or full-power piston, idle too rich or too fast, stuck accelerator-pump check valve, or a leaky carburetor.

2. Lack of engine power, acceleration, or high-speed performance can result from a malfunctioning accelerator pump, from the power step-up on the metering rod not clearing the jet, from dirt or gum clogging fuel nozzle or jets, from a stuck power piston or valve, a low float level, dirty air filter, choke stuck or not operating, air leaks into manifold, antipercolator valve stuck, throttle valve not fully opening, or a rich mixture due to causes listed in the previous paragraph.

3. Poor idle can result from an incorrectly adjusted idle mixture or speed, a clogged idle circuit, or from any of the causes listed in the previous paragraph.

4. Failure of the engine to start unless primed could be due to carburetor jets or lines being clogged, a defective choke, a clogged fuel filter, or air leaks into the manifold.

5. Hard starting with the engine warm could be due to a defective choke, closed choke valve, or improperly adjusted throttle-cracker linkage.

6. Slow engine warm-up could be due to a defectively operating choke.

7. A smoky, black exhaust is due to a very rich mixture; carburetor conditions that could cause this are listed in item 1, above.

8. If the engine stalls as it warms up, it could be due to a defective choke or closed choke valve.

9. If the engine stalls after a period of high-speed driving, it could be due to a malfunctioning antipercolator.

10. If the engine backfires, it could be due to an excessively rich or lean mixture.

11. If the engine runs but misses, it could be that the proper amount and ratio of air-fuel mixture is not reaching the engine, and

this might be due to clogged or worn carburetor jets or to an incorrect fuel level in the float bowl.

Several of the conditions noted above can be corrected by carburetor adjustment. Other conditions require removal of the carburetor from the engine so that it can be disassembled, repaired, and reassembled. The following section describes various adjustments to be made to the carburetor, while later sections describe in detail how specific carburetors are torn down and rebuilt.

§168. Typical carburetor adjustments Since a great variety of carburetors (estimated at over 500 models) have been used on automotive vehicles in the past 10 years, it is obviously beyond the scope of this book to provide detailed adjustment and servicing procedures on all. However, typical adjusting procedures as well as specific teardown and rebuilding procedures on popular model carburetors are included. This information will give the reader a general idea of how these various operations are performed. However, in actual practice in the automotive carburetor shop, the mechanic should always refer to the carburetor manual for the specific carburetor he is servicing. This assures proper adjustment and relationship of all parts on reassembly.

Many years ago, the various gasoline-discharge jets on the carburetor were adjustable, and it was sometimes difficult to balance them all for proper engine performance. Today, however, jets are fixed on most applications and, with the exception of the idle-mixture jet, require no adjustment. Usually, the only adjustments to be made on the modern carburetor besides the idle-mixture jet are establishment of the proper mechanical linkage measurements between the moving parts in the carburetor. Some carburetors require only a few adjustments, such as the idling-mixture, idling-speed, float-level, and metering-rod-linkage with the throttle. Others require, in addition, adjustment of the antipercolator, accelerator-pump linkage, and the slow- and fast-idle speeds. Adjustments discussed below are not necessarily given in proper sequence; since the sequence varies somewhat from one carburetor to another.

NOTE: Carburetor adjustments should not be made until other components affecting engine operation are known to be in order. Engine compression, valve action, ignition system, fuel pump, fuel strainers, air cleaner, and manifold heat-control valve must all be within operating specifications. There must be no air leaks into the intake manifold, and throttle linkage must be correctly adjusted. Adjusting the carburetor to compensate for faulty conditions elsewhere will probably further reduce engine performance and increase fuel consumption.

§169. Idle-speed and idle-mixture adjustments The idle-speed and idle-mixture (Fig. 10-1) are the most commonly made adjustments on the carburetor and are usually made together. Use of an intake-manifold vacuum gauge (§132) will help in achieving a steady idle

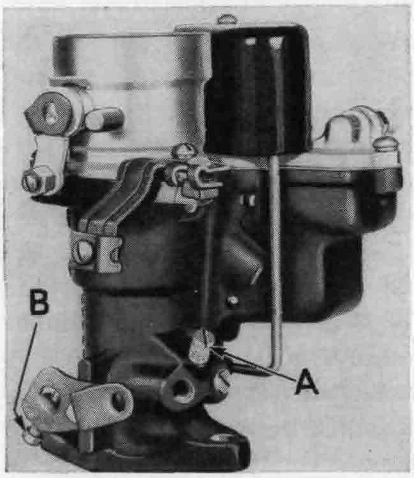


FIG. 10-1. Idle-mixture screw (*A*) and idle-speed adjusting screw (*B*) on one type of carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

(as indicated by a steady vacuum reading). The throttle adjusting screw, which controls idling speed, should be adjusted so that the engine idles at the specified engine rpm (revolutions per minute). This is approximately one turn of the adjusting screw back from fully closed throttle. Most car manufacturers give adjusting specifications in terms of engine rpm. To measure engine rpm, a special rpm indicator, or tachometer, is needed, as explained in §133. The idle-mixture adjustment is made by turning the idle-mixture (needle) screw. Correct setting will give smoothest idle. The proper setting on most carburetors is one to two turns of the idle-mixture screw back from the fully seated position. To set the idle mixture accurately, a vacuum gauge (§132) should be used. The vacuum gauge is attached to the intake manifold, and the idle-mixture screw is adjusted until the vacuum gauge gives a maximum reading with a steady needle. After the idle-mixture setting is made, it may be necessary to readjust the idle speed slightly so as to return the setting to the specified rpm.

On some applications the carburetor has a fast-idle cam that is tied in with the automatic choke. With the engine cold, the choke valve is closed, and in this position linkage between the choke valve and fast-idle cam forces the high point on the cam to come into position under the throttle adjusting screw (Fig. 4-30). This

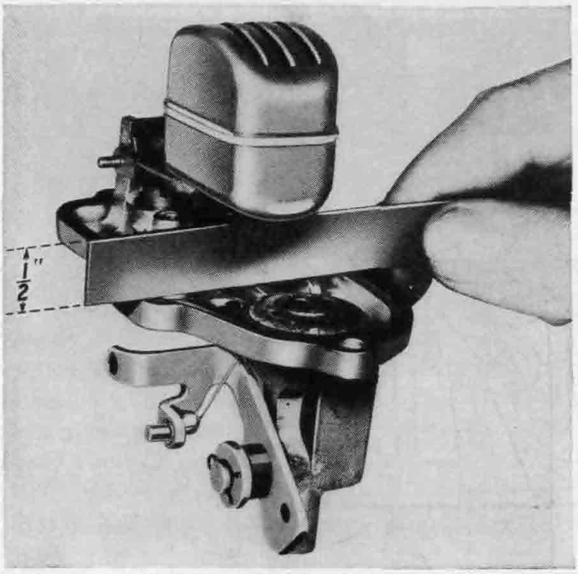


FIG. 10-2. Checking the float-level height between float and bowl cover on one type of carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

causes a fast idle with the engine cold. When the engine warms up, the choke valve opens and forces the fast-idle cam to rotate so that the high point moves out from under the adjusting screw. In this position the engine has a normal slow idle. Adjustment on this type of carburetor is made by obtaining proper slow idle, as above, and then adjusting linkage to the choke valve to obtain proper fast-idle speed.

§170. Float level After considerable service, the lip on the float level that actuates the needle valve tends to wear, so that the float level rises, permitting flooding and an excessively rich mixture. On the other hand, an excessively low float level will cause a mixture that is too lean. On some applications, it is possible to install a float-level gauge on the carburetor, while on others an inspection plug may be removed for checking the float-level height without disassembling the carburetor. On other applications the float-bowl cover must be removed and the fuel height or float-level position measured. Measurement is usually taken between the fuel or float and the top of the bowl (Fig. 10-2) or between the bowl cover and a marking on the float. Adjustment is made by bending the lip that actuates the needle valve or the arm (or arms) supporting the float. The float itself should never be bent.

§171. Accelerator pump For various climatic conditions, various lengths of accelerator-pump-piston travel are desirable. During

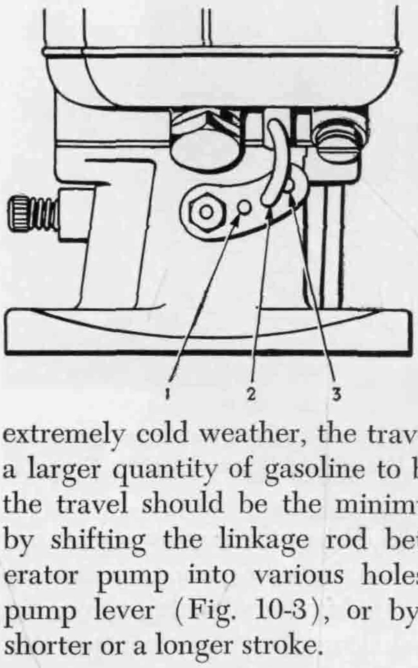


Fig. 10-3. Accelerator-pump-lever linkage adjustments. Position 1 provides a short stroke for summer operation, position 2 provides an intermediate stroke for average operation, and position 3 provides a long stroke for winter operation. (*Plymouth Division of Chrysler Corporation*)

extremely cold weather, the travel should be the maximum to allow a larger quantity of gasoline to be discharged. During hot weather, the travel should be the minimum. Adjustment is provided either by shifting the linkage rod between the throttle and the accelerator pump into various holes provided in the throttle or the pump lever (Fig. 10-3), or by bending the linkage to secure a shorter or a longer stroke.

§172. Metering rod Various sizes of metering rod can be installed on carburetors using this type of high-speed, full-power circuit control to secure a leaner or a richer mixture when this circuit is operating. The linkage between the throttle and the metering rod must be correct so that the metering rod will rise to permit the high-speed, full-power circuit to come into action at the correct throttle opening. This linkage may be checked by using a gauge

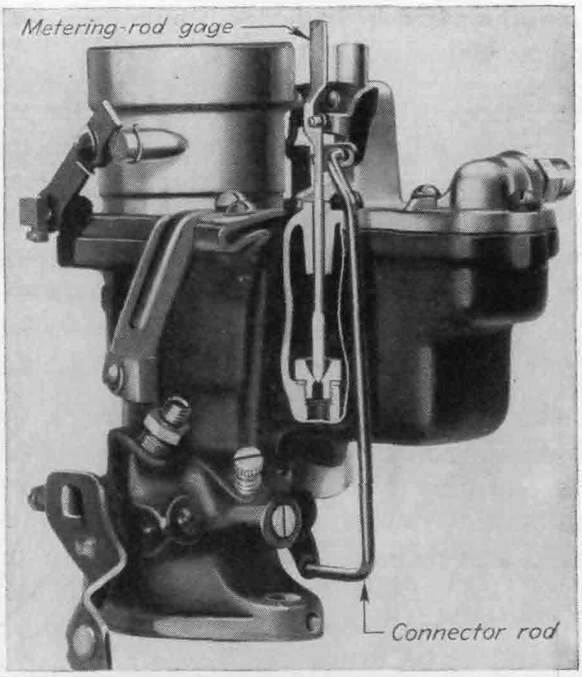


FIG. 10-4. Checking metering rod and throttle relationship with gauge on one type of carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

installed in the carburetor in place of the metering rod (Fig. 10-4), and adjustment is accomplished by bending the throttle connector rod to secure the proper relationship.

§173. Antipercolator The antipercolator must be adjusted to open with the throttle in the closed position. This adjustment is made by opening the throttle some definite amount (for instance, by moving the fast-idle cam around so that the high point is under the throttle adjusting screw) and then measuring the clearance between the antipercolator rocker-arm level and the operating lever

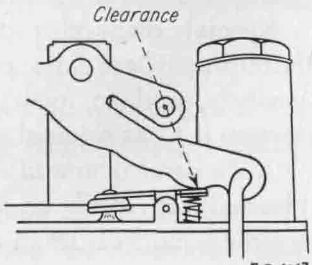


FIG. 10-5. Antipercolator clearance adjustment point on one type of carburetor.

(Fig. 10-5). Adjustment is made by bending the rocker arm to secure the proper clearance.

§174. Throttle linkage The throttle linkage on the car must be adjusted to provide full-throttle opening when the foot pedal is fully depressed, proper control of hand throttle (where used), and correct throttle-cracker adjustment for starting. In addition, the throttle must be fully closed when the foot pedal is in the released position. The procedures for making these adjustments vary from car to car, so the manufacturer's specifications should be followed when adjustments are necessary.

§175. Carburetor removal To remove a carburetor, first take off the air cleaner and then disconnect the throttle and choke linkages. Disconnect hot-air tube to choke (if present). Disconnect the fuel line and distributor vacuum-advance line from the carburetor, using two wrenches, as necessary, to avoid damage to the lines or couplings (see §155). Disconnect wires from switches and other electric controls (where present). Take off carburetor attaching nuts or bolts, and lift off carburetor. Try to avoid jarring the carburetor, since it might have accumulations of dirt in the float bowl and rough treatment might stir this dirt up and cause it to get into carburetor jets or circuits.

After the carburetor is off, it should be put in a clean place where dirt or dust cannot get into the fuel inlet or other openings.

§176. Carburetor overhaul procedures Disassembly and reassembly procedures on carburetors vary according to their design; the manufacturer's recommendations should be carefully followed. The time required to overhaul a carburetor varies from approximately ¾ to 1¾ hours, according to type. Special carburetor tools are required. Gauges particularly are needed to gauge clearance, float centering, float height, choke clearance, and so on.

Special carburetor overhaul kits are supplied for many carburetors. These kits contain all necessary parts (jets, gaskets, washers, and so forth) required to overhaul the carburetor and restore it to its original performing condition.

1. *General overhaul instructions.* Jets or nozzles should never be cleaned with drills or wires since this would probably enlarge the openings and cause an excessively rich mixture. Instead, the open-

ings should be cleaned out with denatured alcohol or similar recommended solvent. This solvent will remove any gum that is clogging the opening. Similarly, all circuits or passages in the carburetor body should be washed out with solvent and then blown out with compressed air. Double-check passages with a flashlight to be sure they are cleaned out.

Power pistons that are scored or burred should be replaced; the piston must slide freely in the bore in the carburetor body. Worn or scored needle valves or seats must be replaced. Filter screens must be clean. Accelerator-pump plungers must fit snugly in their wells. If the leather is damaged, a new plunger must be used.

If the air horn is coated with dirt or carbon, it should be scraped lightly or sanded with sandpaper and then washed in solvent. Never use emery cloth, since particles of emery may embed and later loosen to clog jets or circuits in the carburetor.

Be sure that all residue is washed from the carburetor and that the carburetor body is clean inside and out.

New carburetor gaskets should be used when the carburetor is reassembled. The old gaskets are usually damaged when the carburetor is torn down, and there is no use taking a chance on a leak developing later that would require disassembling the carburetor again.

2. *Cautions.* Several important cautions should be observed in carburetor work.

a. Be sure your hands, the workbench, and tools are really clean.

b. Gasoline, as well as denatured alcohol or other solvent used to dissolve the gum from carburetor jets and other parts, is highly flammable. Extreme care must be used in handling these liquids, particularly some of the solvents, since they will ignite easily.

c. Handle the air hose with care. Remember, high-pressure air can drive dirt particles at high speed. If one of these particles should be blown into the eye, it might damage the eye irreparably. Wear goggles when using the air hose to be safe.

d. Never clean carburetor jets or orifices with wire or drills. This would probably enlarge the openings and result in excessive fuel consumption.

e. Always use new gaskets on reassembling the carburetor.

f. The correct carburetor parts must be used on reassembly. Substitute parts that may be somewhat different should not be installed unless the carburetor manual specifically states that this may be done. Otherwise, performance and economy may be lost.

g. Carburetor adjustments should not be made until other components affecting engine operation are in good order. Adjusting the carburetor to compensate for faulty conditions elsewhere will probably result in poorer engine performance and higher fuel consumption.

h. Do not oil the automatic choke linkage or the automatic choke.

CHECK YOUR PROGRESS

Progress Quiz 9

Now is your chance to stop and check up on how well you have been progressing in your reading of Chap. 10. This chapter is an important one, since every automotive mechanic should be familiar with carburetors even though he might not specialize in carburetor service work. Since the carburetor is, after all, an integral part of the engine, a mechanic who normally works on the engine, the electrical equipment, or other automotive components should understand the part that the carburetor plays in the operation of the car. The questions below will help you review the general material on carburetor service that you have just covered.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Careless cleaning of fuel nozzles so that they are enlarged will result in *reduced fuel consumption* *lean mixture* *excessive fuel consumption*
2. Dirt or gum in fuel nozzles or jets may cause *excessive fuel consumption* *lack of engine power* *smoky, black exhaust*
3. A high float level may cause *excessive fuel consumption* *a lean mixture* *failure to start except when primed*
4. A choke valve that is stuck in the closed position may cause *an overrich mixture cold* *an overrich mixture hot* *an excessively lean mixture*
5. A clogged fuel nozzle could result in *excessive fuel consump-*

tion *an overrich mixture* *high float level* *failure to start except when primed*

6. A smoky, black exhaust is probably due to *low float level* *a very rich mixture* *a very lean mixture* *clogged idle circuit*
7. The most commonly made adjustments on the carburetor are *idle-mixture and idle-speed* *float level and height* *main-nozzle richness and mixture*
8. During cold-weather operation, it is desirable for the accelerator-pump-piston travel to be *shortened* *lengthened* *slowed down*

§177. Overhauling Chevrolet carburetors A sectional view of a late-model Chevrolet carburetor is shown in Fig. 10-6. This carburetor requires only three adjustments; idle-mixture, idle-speed, and float-level. In addition, on those models so equipped a throttle-return-check adjustment is required. Adjustments, disassembly, inspection of parts, and reassembly of this carburetor are detailed below.

§178. Adjustments (Chevrolet model in Fig. 10-6) Before making any carburetor adjustments, the engine should be thoroughly warmed up. Carburetor-attaching bolts, and manifold-attaching bolts and must be tight so that no air leaks can occur. The idle-mixture and idle-speed adjustments must be made together.

1. Idle-mixture adjustment is made by turning idle-mixture screw (*A* in Fig. 10-7) all the way in and then backing off the screw 1½ to 2½ turns. Then turn screw either way from this position with engine idling to obtain smoothest idle.

Caution: When turning screw in, do not turn it in too tightly, or you will score or scratch the needle valve on the screw.

2. Idle-speed adjustment is made by first making sure hand throttle and choke buttons are pushed all the way in on the instrument panel. Throttle linkage must be free so that throttle stop screw (*B* in Fig. 10-7) is against the stop. Then turn screw in or out to obtain correct idling speed for the engine. Then recheck idle-mixture adjustment to make sure that idle is as smooth as possible.

NOTE: Idle speed varies according to engine model. For example, specifications call for an idle of 450 to 500 rpm on the model 216 engine and 430 to 450 rpm on the 235 engine. An rpm indicator (§133) should be used for accurate setting of the idle speed.

3. Float-level adjustment consists of three parts: adjustment of the float height, centering of the two floats, and float drop.

a. To adjust float height, remove carburetor air cleaner, disconnect choke wire from choke lever, disconnect fuel line from carburetor, hold throttle kick lever out of way, and remove cover assembly by taking out four attaching screws. Lift cover straight up to avoid damaging floats. With cover gasket still in position, upend cover assembly on a flat surface and put special float gauge into position as shown in Fig. 10-8. Tang in center of gauge should be placed in the main discharge nozzle. In this position, the floats should just touch the tops of

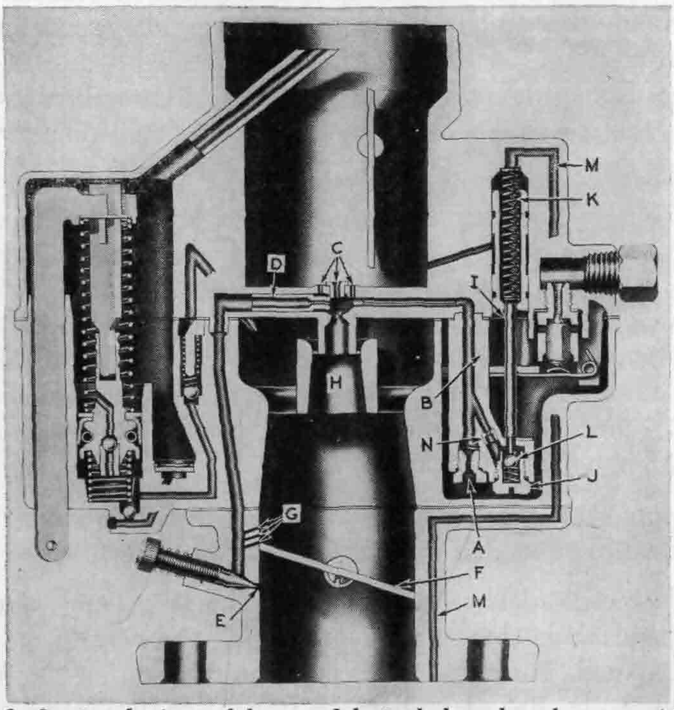


FIG. 10-6. Sectional view of late-model single-barrel carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

A. Main metering jet
B. Main-well support
C. Air bleeds
D. Idle tube
E. Idle port
F. Throttle valve
G. Secondary idle ports
H. Venturi
I. Power piston
J. Power valve
K. Spring
L. Spring-loaded ball
M. Manifold-vacuum passage

the slots in the gauge. If they do not, bend the float arms vertically until they do.

Caution: Do not put pressure on the floats, but do the bending on the arms themselves.

b. To adjust float centering, turn the cover assembly 90 degrees or onto one side (with gauge vertical) and see whether the

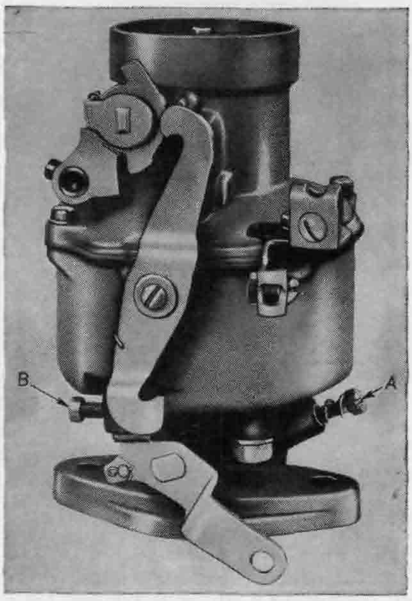


FIG. 10-7. Exterior view of carburetor, showing idle-mixture adjustment screw (*A*) and idle-speed adjustment screw (*B*). (*Chevrolet Motor Division of General Motors Corporation*)

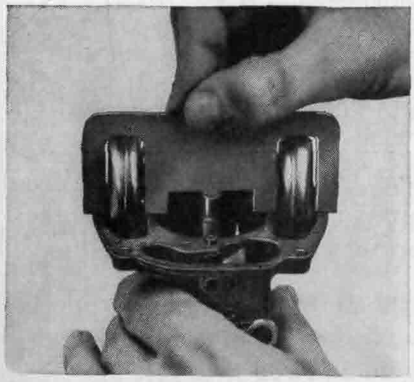


FIG. 10-8. Checking float-height adjustment. (*Chevrolet Motor Division of General Motors Corporation*)

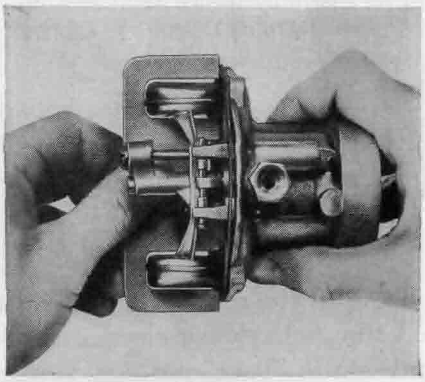


FIG. 10-9. Checking centering of floats. (*Chevrolet Motor Division of General Motors Corporation*)

floats rub the sides of the slots in the gauge (Fig. 10-9). Turn the assembly to one side and then the other to make the check. If either float rubs, bend the float arm to keep it from rubbing. Then recheck level adjustment. This adjustment assures that the floats will not rub the sides of the float bowl.

c. Float drop adjustment is made by turning the cover assembly right side up so that the floats are suspended freely and then

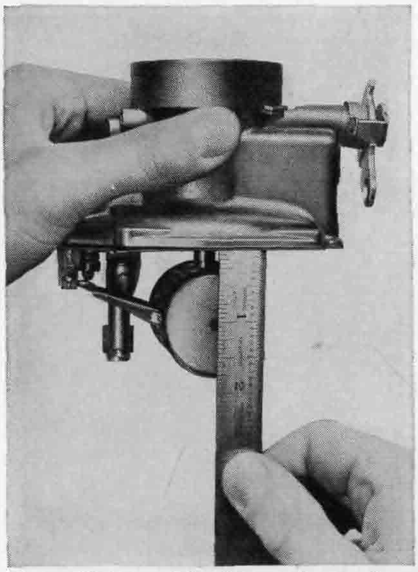


FIG. 10-10. Checking float drop. Cover assembly turned right side up. (*Chevrolet Motor Division of General Motors Corporation*)

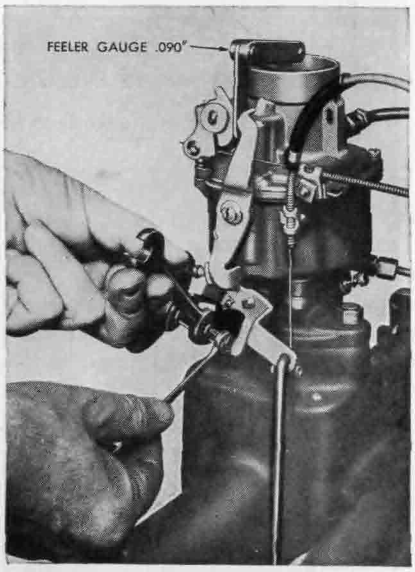


FIG. 10-11. Checking and adjusting throttle-return check. (*Chevrolet Motor Division of General Motors Corporation*)

checking the distance between the bottom of the float and the gasket surface (Fig. 10-10). This distance should be 1¾ inches. If it is not, bend the float tang at the rear of the float assembly. This adjustment assures sufficient needle-valve opening during high-speed operation for adequate fuel entry.

4. Throttle-return-check adjustment is made with an rpm indicator (§133). Air cleaner must be off the carburetor. With transmission in "Park" position, start engine and run it at fast idle until it warms up. Make sure engine is running smoothly at idling speed of 430 to 450 rpm (engine warm) before making throttle-return-check adjustment. Adjust idle speed and mixture if necessary. Then

insert 0.090-inch feeler gauge between carburetor choke lever cam and fast-idle lever as shown in Fig. 10-11. Use one wrench on flat sections of the throttle-return-check shaft to keep it from turning, and turn the adjusting screw with a second wrench as shown in Fig. 10-11. Turn adjusting screw until it just touches the throttle lever contact arm.

§179. Disassembly (Chevrolet model in Fig. 10-6) With carburetor off the engine, clean off dirt from outside of carburetor. During the overhaul, be very particular about dirt (see §148 on cleanliness). Refer to Fig. 10-12 and disassemble as follows.

1. Remove four cover screws, and lift off cover. Hold throttle kick lever out of way, and lift cover straight off to avoid damaging floats.

2. Upend cover assembly on flat surface, take out float hinge pin, lift off the float, and remove the float needle. With wide-tipped screw driver, unscrew float needle seat and remove fiber gasket. Unscrew main metering jet and power-valve assembly, using care to avoid losing spring and ball under valve. Take out attaching screw, and lift straight up on main well support to remove it. Be careful to avoid damaging the main-well tube.

NOTE: Late-model carburetors used on 235 engines have the main-well tube pressed into the air horn and extending deep into the main-well support. On these, the support should not be removed as the air horn, support, and air-horn gasket are serviced as an assembly in case any part requires replacement.

Complete the disassembly of the cover assembly by taking gasket, power piston, and spring from cover.

3. Take pump plunger from float bowl by holding plunger all the way down, removing hairpin retainers from pump link so that link can be detached from throttle lever and plunger. Plunger can then be lifted from bowl, and spring and ball check removed from bottom of the well. Use small screw driver to rotate pump discharge guide until it can be removed from float bowl. Pump discharge spring and ball check will then fall out when bowl is turned upside down. Take off pump-screen retainer and screen.

4. Separate float bowl from throttle body by removing two attaching screws. Idle-adjusting needle and spring should then be removed from the throttle body.

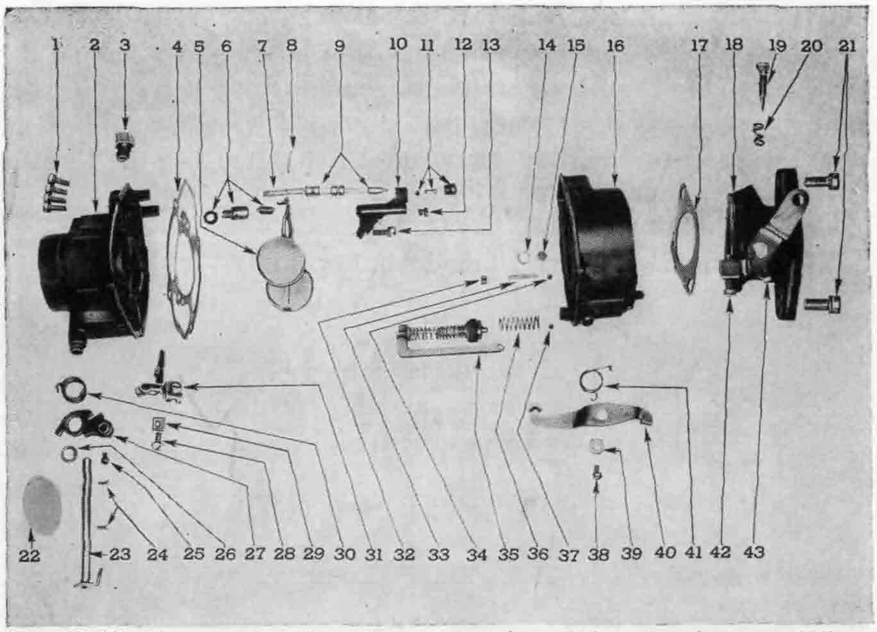


FIG. 10-12. Disassembled view of one type of single-barrel carburetor. (*Chevrolet Motor Division of General Motors Corporation*)

1. Cover-attaching screw
2. Air horn
3. Fuel-inlet fitting
4. Air-horn gasket
5. Float
6. Float needle, seat, gasket assembly
7. Power spring
8. Float hinge pin
9. Power piston
10. Main-well support
11. Power-valve assembly
12. Main metering jet
13. Attaching screw
14. Pump-screen retainer
15. Pump screen
16. Float bowl
17. Throttle-body gasket
18. Throttle-body assembly
19. Idle adjusting needle
20. Idle needle spring
21. Throttle-body screw
22. Choke valve
23. Choke shaft
24. Choke-valve screw
25. Choke-lever screw
26. Choke-lever retainer
27. Choke lever
28. Bracket screw
29. Bracket nut
30. Choke-shaft spring
31. Choke bracket
32. Pump discharge guide
33. Pump discharge spring
34. 3/16 steel pump discharge ball
35. Pump-plunger assembly
36. Pump return spring
37. 5/32 aluminum pump check ball
38. Throttle-kicker screw
39. Throttle-kicker washer
40. Throttle kicker
41. Throttle-kicker spring
42. Throttle-valve screw
43. Throttle shaft

5. Inspect all parts. Section 176 covers general overhaul instructions and explains how to clean and inspect carburetor parts. Pay special heed to the fit of the throttle shaft in the throttle body. If it is loose, the throttle-body assembly must be replaced since looseness will throw off throttle valve fit and alignment of the throttle valve with the idle discharge holes.

§**180. Reassembly** (Chevrolet model in Fig. 10-6) Essentially, reassembly is the reverse of disassembly. Following are the special points to watch.

1. Install idle needle screw and spring in throttle body, tighten until finger tight, and back off about two turns.
2. Using a new throttle-body gasket, attach body to bowl. Place clean pump screen in bottom of bowl, and lock retainer in position. Drop small aluminum ball in pump well, making sure that it will lift freely from its seat (that is, that it does not stick). Put pump return spring in pump well, and center it by compressing it with finger. Install pump plunger, and connect pump link to throttle lever and pump rod. Attach link with hairpin retainers. Drop large steel ball into pump discharge cavity, and put bronze spring on top of ball. Put end of pump discharge guide into bronze spring, and press guide down until it is flush with bowl surface.
3. Assemble cover by installing float needle seat, using a new fiber washer. Then put float needle in place. Use a new air-horn gasket. Put power-piston spring and piston in place, and attach main-well support to air horn. Install main metering jet and tighten securely. Hold the power-piston stem down, and install ball, spring, and plug and tighten securely. Attach float with hinge pin. (Float tang must face air horn.) Adjust float as already described, and then install cover assembly on float, attaching it with four screws well tightened. Hold throttle kick lever out of way when putting cover into position on bowl.

§**181. Overhauling Plymouth carburetors** Four adjustments are provided on Plymouth carburetors: idle speed, idle mixture, float height, and accelerator-pump setting. Adjustments, disassembly, inspection, and assembly procedures are detailed below.

§**182. Adjustments** (Plymouth) Before making any adjustments, the engine must be at operating temperature.

1. *Idle speed and idle mixture.* First adjust the idle speed to between 450 and 500 rpm. Then turn idle-mixture screw to give smoothest operation. A vacuum gauge and a tachometer will help in making the idle-mixture and idle-speed adjustments (§169).

2. *Float height.* Remove air cleaner and air horn from carburetor so that float is exposed (Fig. 10-13). Use special gauge as shown, and raise the float with finger pressed against the vertical lip until the needle valve closes. If a gauge is not available, lay straightedge on float-bowl flange above the float in place of the gauge. Then measure down to float, when float is held in raised position as explained above. Distance should be $\frac{5}{64}$ inch (plus or minus $\frac{1}{64}$ inch). Adjust by removing float and bending the vertical lip only. Bend toward float to raise float, away to lower float.

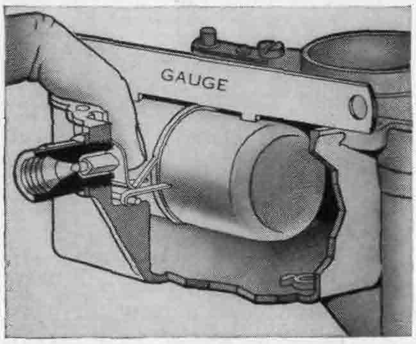


FIG. 10-13. Checking float height. (*Plymouth Division of Chrysler Corporation*)

3. *Accelerator-pump setting.* The procedure of changing the accelerator-pump setting has already been covered in §171 (see Fig. 10-3).

§183. Disassembly and reassembly (Plymouth) With carburetor off the engine, clean off dirt from outside of carburetor. During overhaul, be very particular about dirt (see §148 on cleanliness). Disassemble as follows.

1. With air horn off, take off hinge pin and float. Take out needle valve, and feel with the fingernail for any ridges or signs of wear on the needle. If the needle requires replacement, replace the needle seat and gasket, too, since the seat and needle valve are matched at the factory and are serviced together in matched sets.

2. Check the main metering jet and vent tube (Fig. 10-14) after

cleaning them with solvent and compressed air. Replace as necessary.

3. The power step-up system is shown schematically in Fig. 10-15. Piston can be checked for free operation by pushing it down about 1/64 inch and then seeing if it will move up and down freely. If it sticks or binds, disassemble it, clean the piston and bore, or

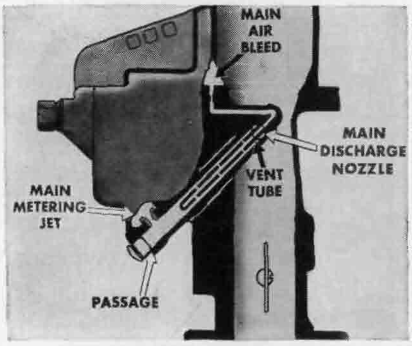


FIG. 10-14. The main metering jet and the vent tube in a carburetor. (*Plymouth Division of Chrysler Corporation*)

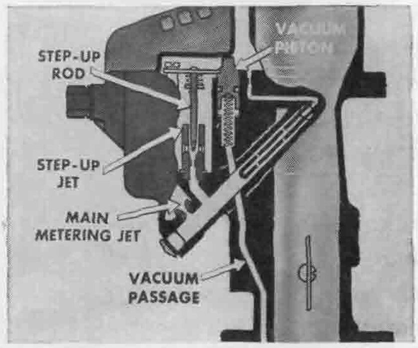


FIG. 10-15. Power step-up system showing locations of piston, rod, and jet. (*Plymouth Division of Chrysler Corporation*)

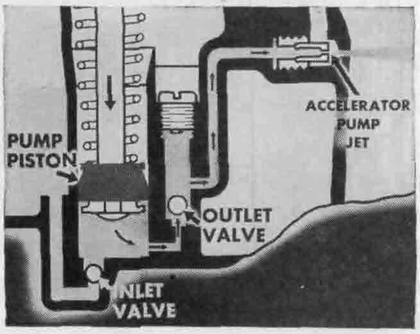


FIG. 10-16. Pump piston, valves, and pump jet in accelerator system. (*Plymouth Division of Chrysler Corporation*)

install new parts. With the piston pushed all the way down, there should be some clearance between the top of the plate and step-up rod. Bend the step-up rod plate slightly, if necessary, to obtain a minimum of 0.010-inch clearance.

4. Inspect the idle orifice tube and air-bleed passage to make sure they are clean. Install a new tube if the old one is damaged.

5. To remove the accelerator-pump jet, take out the rivet plug and unscrew the jet (Fig. 10-16), using a narrow-tipped screw

driver that will not damage the threads in the body. Clean the jet with solvent and compressed air. Lift out the accelerator pump, and examine the leather on the plunger. If it is hard or damaged, install a new piston. Check the inlet and outlet ball checks for action, and clean them with solvent and compressed air.

6. Inspect all parts. Section 176 covers general overhaul instructions and explains how to clean and inspect carburetor parts. In addition, special inspection hints are given in the disassembly instructions above. Pay special heed to the fit of the throttle shaft in the throttle body. If the fit is loose, calibration and proper action of the idle- and low-speed circuits will be lost. In such case, the body and shaft should be replaced.

7. Essentially, reassembly is the reverse of disassembly. As a rule, disassembly of this carburetor need be carried no further than is necessary to take care of some defect. However, when a carburetor is partly torn down, it is little additional trouble to complete the disassembly so as to check everything in the carburetor. Reassembly then consists of putting the various parts back into their original places. Since the carburetor is very simple in design, no difficulty should be experienced in reassembly.

§184. Overhauling two-barrel carburetors Several manufacturers make two-barrel, or dual, carburetors. Many automobile manufacturers use this type of carburetor. They are all rather similar in basic design and operation. However, disassembly and reassembly procedures do vary from model to model. The typical procedures described below apply to the carburetor used on recent Buick automobiles, which is illustrated in Figs. 4-2, 4-8, and 4-11. Be sure to refer to the manufacturer's service manual before attempting to disassemble, adjust, and repair other models of two-barrel carburectors.

§185. Adjustments (two-barrel carburetor) Adjustments that can be made without disassembling the carburetor include idle-speed, idle-mixture, fast-idle, and choke adjustments. Choke adjustment is covered in §151.

1. *Initial idle-mixture and idle-speed adjustments.* With engine stopped, turn both idle needles (or idle-mixture screws, as they are also called) in until they seat lightly. Do not turn in tight since this will damage valves and seats. Back off each needle exactly one turn.

Then back off the throttle stop screw, and hold the fast-idle cam in open-choke position so throttle valves can close fully. Turn throttle stop screw out until it no longer touches the arm on the throttle lever. Next, turn it in until it just contacts the arm. Then turn screw in exactly one complete turn. This gives an engine idle speed of about 450 rpm.

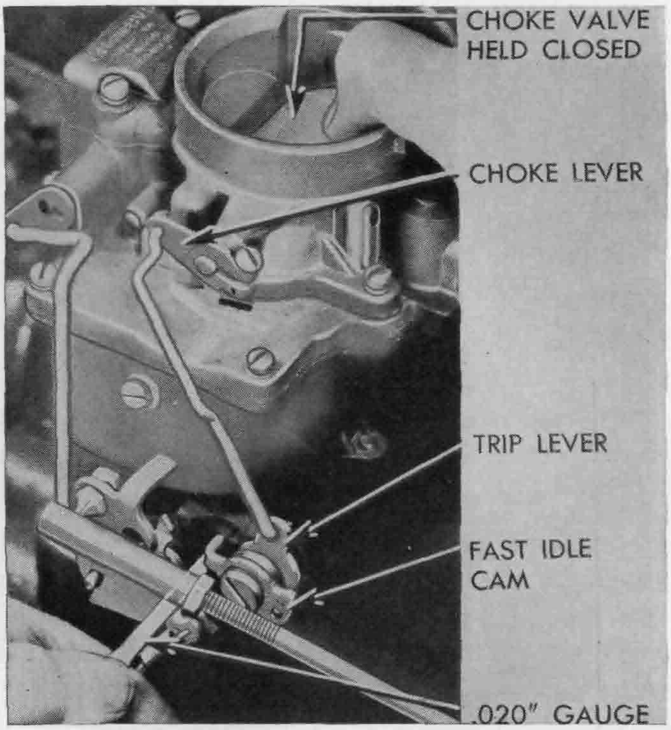


FIG. 10-17. Checking fast-idle-cam clearance. (*Buick Motor Division of General Motors Corporation*)

2. *Final idle-mixture and idle-speed adjustments.* After the above initial adjustments are made, start the engine and allow it to idle until the engine is at operating temperature. Then turn both needle valves in exactly the same amount until the engine begins to roll, or run unevenly. Then turn both needle valves out exactly the same amount until the engine once again begins to roll, or run unevenly. Finally, turn both needles to a position exactly halfway between the two extreme positions. The throttle stop screw may require some readjustment as the needle valves are changed in order to

maintain engine idling speed at 450 rpm. These final adjustments may also be made with the help of a vacuum gauge and a tachometer (§169).

3. Fast idle. Fast idle is tied in with the choke unloader and position of the idle adjustment screw. To adjust, first remove the air cleaner. Then hold choke valve closed and, with cam trip lever in

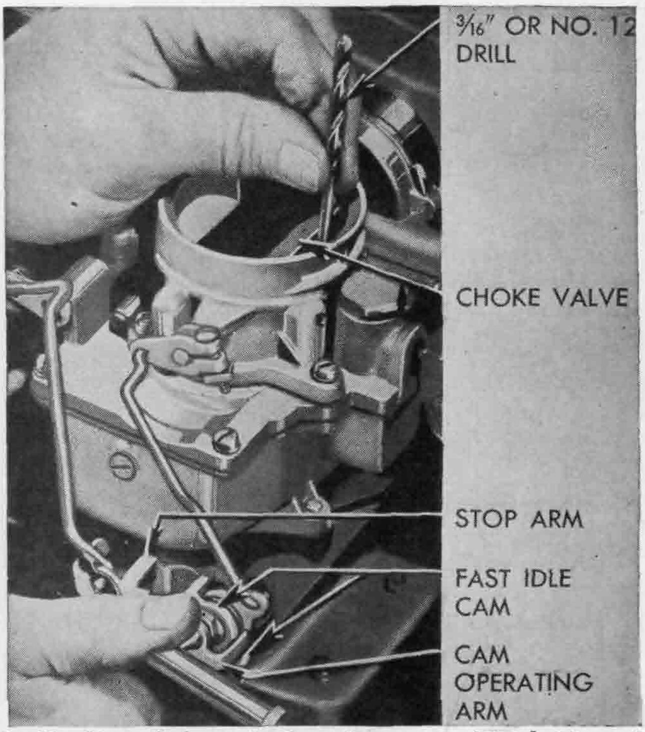


FIG. 10-18. Checking choke unloader adjustment. (*Buick Motor Division of General Motors Corporation*)

contact with the fast-idle cam, check clearance between the fast-idle-cam arm and the boss on the carburetor body. Clearance should be 0.020 inch (Fig. 10-17). To adjust, loosen lock screw on choke lever, hold choke valve closed, and turn lever slightly on choke-valve shaft. Tighten lock screw and recheck.

Next, check the choke unloader adjustment (which controls the amount of choke opening as throttle is opened). Open the throttle until the stop arm on the throttle-shaft lever hits the boss on the body flange. Check the clearance between the choke valve and the air horn (Fig. 10-18) with a $\frac{3}{16}$-inch round gauge or No. 12 drill. To adjust, bend the cam-operating arm on the throttle-shaft lever.

Finally, to set the fast idle, turn the fast-idle adjustment screw to obtain an engine speed of 1,200 rpm with the engine warm.

§186. Disassembly Be very particular about dirt during carburetor overhaul. Remember that it takes only a tiny particle of dirt in the right (or wrong) place to change the operating characteristics of the carburetor (see §148).

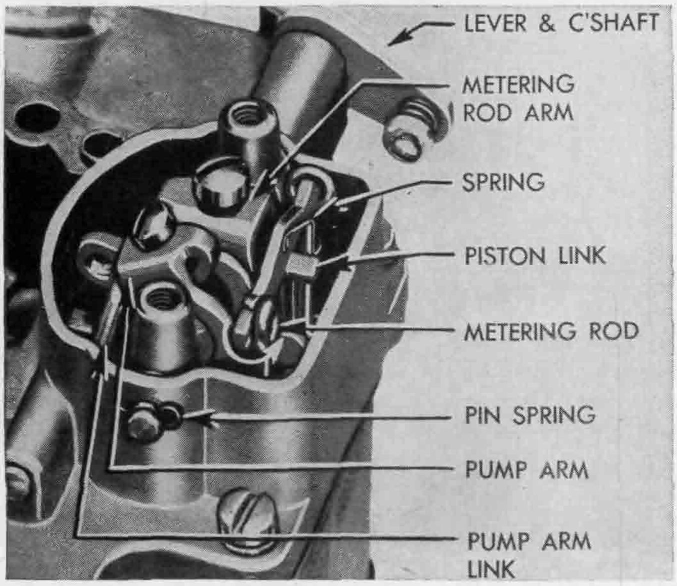


FIG. 10-19. Removing metering rods and other operating parts. Rod is unhooked by turning it as shown by white arrow. (*Buick Motor Division of General Motors Corporation*)

1. With carburetor off engine, remove air horn and disassemble choke as already explained (§152).
2. Take off bowl strainer by removing nut and gasket.
3. Detach throttle connector rod from pump operating lever. Remove rod by pushing retainer off lower end of rod.
4. Remove dust cover. Turn metering rods so that eyes slip off pins on piston link (Fig. 10-19) and lift rods out. Do not bend rods.
5. Loosen the screws in the metering-rod arms, pull pin spring from end of shaft, and pull shaft out, removing arms and link at same time.

6. Note location of the code tag and wire clip so they can be reinstalled in their correct positions; then take off bowl cover. Be careful not to damage the float.

7. Swing vacuum piston to one side to detach it from link. Then take link from cover. Take off float assembly by withdrawing pin, and take out needle. Remove gasket and two low-speed jets as necessary.

8. From main body remove vacuum-piston spring, pump-plunger

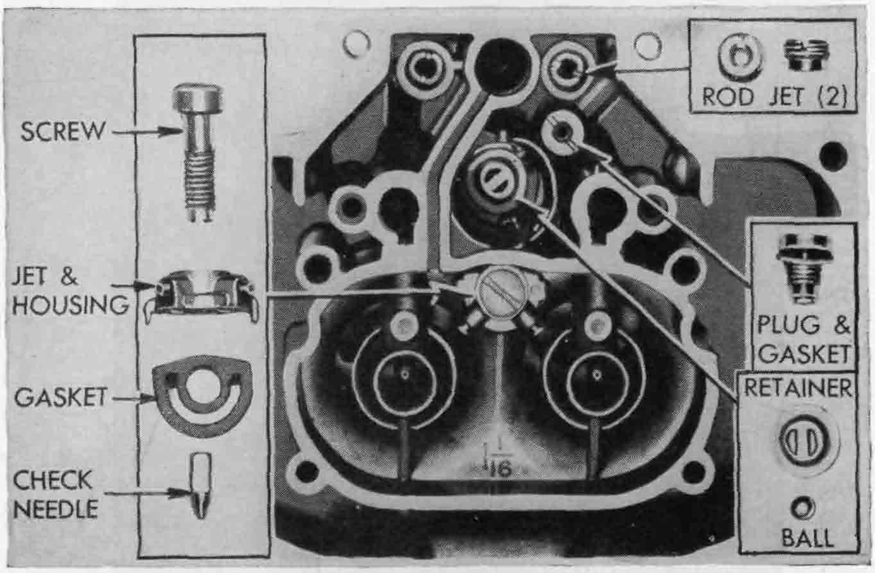


FIG. 10-20. Location of jets, housing, and other parts in main body. (*Buick Motor Division of General Motors Corporation*)

assembly, lower pump spring, screw, jet and housing assembly, gasket, and pump check (Fig. 10-20).

9. Remove other parts from main body, including rod jets, pump-relief plug and gasket from bowl, and pump intake check ball retainer (Fig. 10-20). Use a wire with a hook on the end of it to remove retainer. Take off body flange assembly and gasket.

10. Disassemble vacuum switch by removing hold-down clip (hold terminal cap in place during this operation). Then remove cap and switch return spring, and lift out guide block with contact spring and shims. Do not lose timing shims or the spring washer on the contact spring. Turn body flange over so that plunger and ball drop out in the hand.

11. Remove throttle valves from shaft if necessary to remove shaft from body flange. Shaft should be tapped out with rawhide mallet if it sticks. Fast-idle cam and cam trip lever can then be removed. Idle-mixture screws can then be taken out and, if necessary, idle-port rivet plugs can be removed with special rivet extractor.

12. Inspect all parts. Section 176 covers general overhaul instructions and explains how to clean and inspect carburetor parts. In addition, note that the main nozzles are not to be removed from the main body under any condition. If the main nozzles are damaged, a new body is required. Pay special heed to the fit of the throttle shaft in its bearings. Excessive clearance will permit air leaks that will interfere with performance.

§187. Reassembly Always use all new gaskets on reassembly. In addition, special treatment of certain gaskets is required. Always soak new needle-seat, bowl-strainer-nut, and pump-relief-plug gaskets in 90-proof denatured alcohol for 15 minutes, then install on part and let dry before installing the part.

1. To assemble body flange, drive in new idle-port rivet plugs, and put fast-idle cam and cam trip lever over fast-idle screw so that tongue on trip lever is held in the notch in cam by hooked end of cam spring (Fig. 10-21). Install parts on body flange. Slide throttle shaft into body flange with lever at the closed-throttle position. Put shaft retaining ring over end of shaft with prong points out, and push ring in against body flange to eliminate shaft end play. Install throttle valves on shaft with small "c" in circle toward idle ports. Back off throttle lever adjustment screw, fully close and center throttle valves, and tighten screws. Double-check centering of valves by holding body flange up to light. Then stake screwheads and screw shanks lightly. Install springs and idle adjustment screws in body flange. Assemble vacuum switch into body flange.

2. Install intake check ball and retainer in main body with a special tool that will assure seating of the retainer in recess at bottom of pump cylinder. Attach body flange to main body, using a new gasket. Install, in main body, pump-relief plug and gasket, metering-rod jets, pump check needle (pointed end down), gasket, pump jet housing assembly, and attaching screws. Put vacuum-piston spring and lower pump spring in main body, and install

pump plunger in cylinder, using care to avoid creasing or curling edges of plunger leather washer.

3. On cover, install new seat and gasket if old float needle seat has been removed. Tighten seat firmly but avoid distortion. Attach float needle to float lever, and install float assembly with pin. Adjust float and lever assembly with special gauge in place as shown in Fig. 10-22. With gasket off, bowl cover inverted, and float assembly resting on seated needle, the floats should just touch the outer sides of the gauges and the lower bar of the gauge. Bend arms as shown at *X* in Fig. 10-22 to adjust.

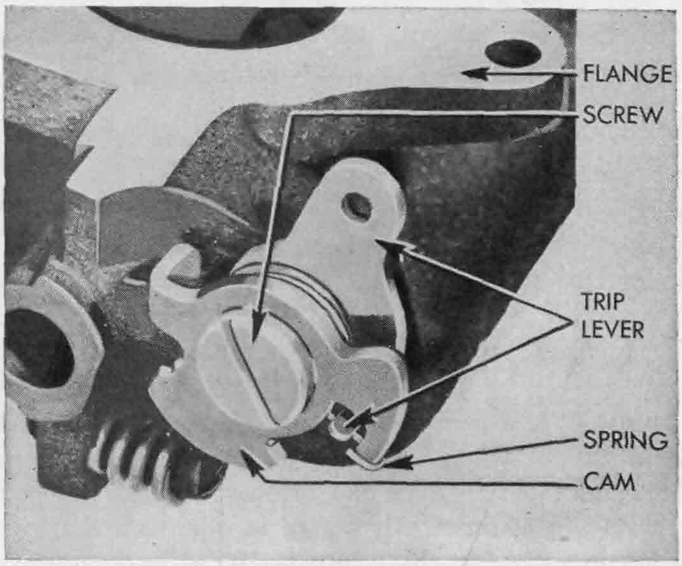


FIG. 10-21. Relationship of fast-idle cam, spring, and trip lever. (*Buick Motor Division of General Motors Corporation*)

4. With adjustment complete, remove float assembly and install both low-speed jets and a new gasket. Then replace float assembly. Install vacuum-piston link (lip at center opening points out). Attach piston to link. Carefully place bowl cover on main body, guiding piston and pump-plunger rod into their proper places in body and cover.

5. Coat pump operating shaft with light graphite grease, and start it into bearing in bowl cover. Hold the metering-rod arm so that it engages the opening in the piston link and the pump arm so that it extends over the pump-plunger rod. Push shaft through

one arm and then the other. Install pin spring on end of shaft. Center pump arm over plunger rod, and tighten lock screw. Install pump-arm link in plunger rod and inner hole of pump arm, and install pin spring. Ends of links should point toward shaft arm. Attach throttle connector rod first to throttle-shaft lever (with retainer) and then to pump operating shaft.

6. Adjust accelerating-pump plunger with throttle lever stop screw backed out and fast-idle cam in the "hot" position so throttle can be fully closed. Then measure distance from the upper end of the pump-plunger rod up to the edge of the bowl cover, using a

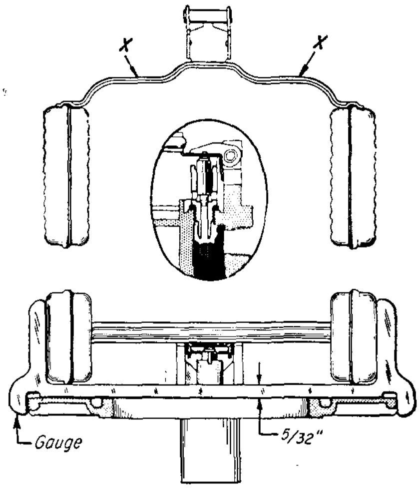


FIG. 10-22. Check of float-level height and adjustment of float assembly. (*Buick Motor Division of General Motors Corporation*)

narrow steel scale as shown in Fig. 10-23. The correct distance should be 5⁄16 inch. Adjustment is made by bending throttle connector rod at the upper angle.

7. Insert ends of metering rods in hooked ends of metering-rod spring, and push rods down to where eyes can rotate over pins on piston link. Avoid bending rods. Adjust rods, after adjusting accelerator-pump plunger, by backing out throttle level stop screw so throttle closes completely. Loosen metering-rod-arm clamp screw (Fig. 10-24), and press down on piston link until metering rods bottom in carburetor body. While holding rods down and throttle closed, revolve metering-rod-arm until tongue on arm just touches lip of piston link. Then tighten metering-rod-arm clamp screw.

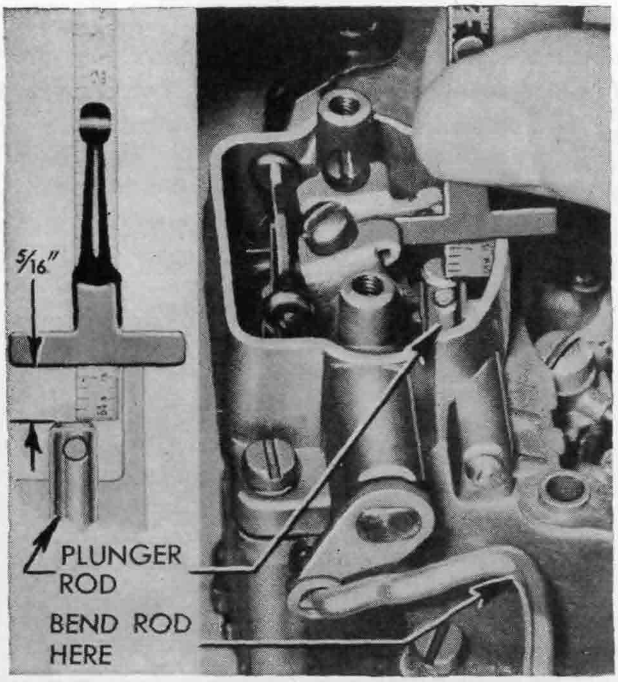


FIG. 10-23. Checking adjustment of accelerator-pump plunger with scale. (*Buick Motor Division of General Motors Corporation*)

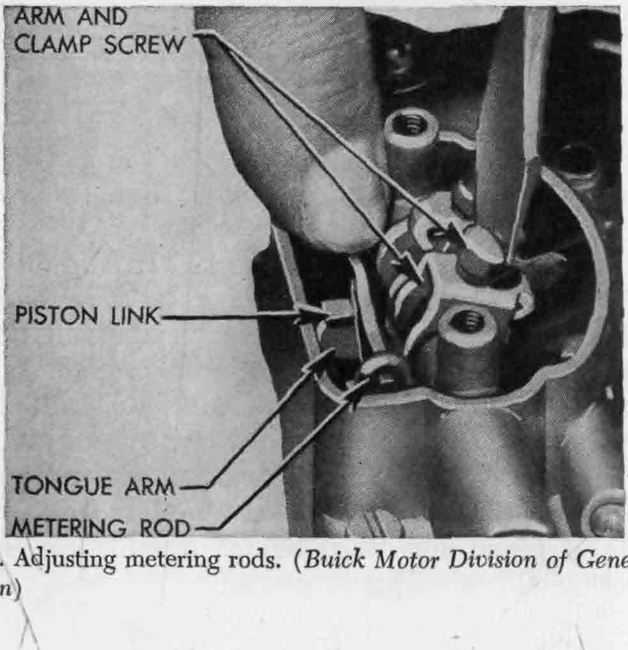


FIG. 10-24. Adjusting metering rods. (*Buick Motor Division of General Motors Corporation*)

8. Pack dust-cover screw holes in bowl cover with light graphite grease, and install dust cover. Install bowl strainer and nut with new gasket. Assemble and install air horn with choke. Adjust carburetor as already explained.

§188. Overhauling Ford carburetors Several models of carburetors have been used in recent years on Ford cars. Adjustments and overhaul procedures on two of these models are outlined below. The first carburetor discussed was used on all V-8 engines up to and including the 1951 engine; the second carburetor discussed has been used on V-8 engines since 1952.

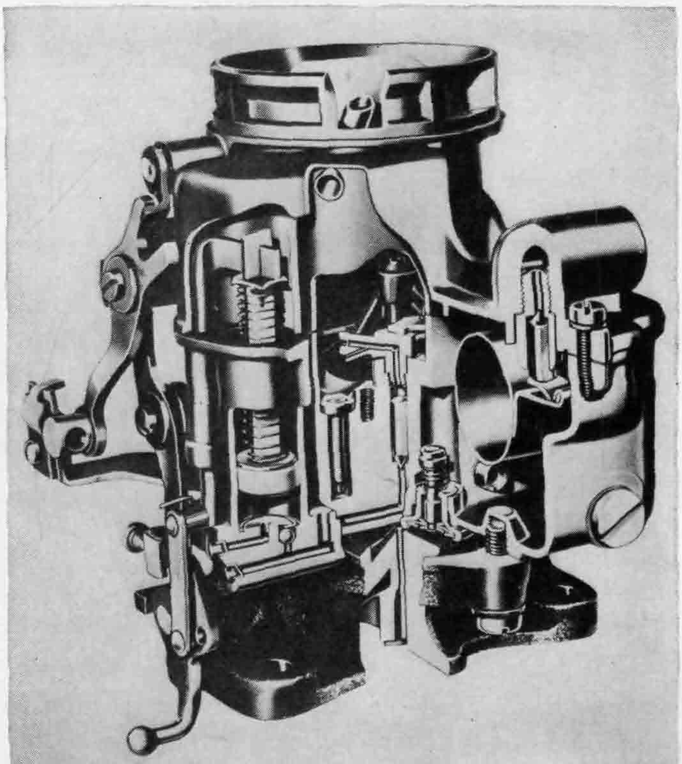


FIG. 10-25. Partial cutaway view of a carburetor showing accelerator pump and high-speed circuits. (*Ford Motor Company*)

§189. Adjustments on carburetors shown in Fig. 10-25 Adjustments required on this carburetor include idle-fuel-mixture, idle-speed, accelerator-pump-stroke, and float-level.

1. *Idle-fuel-mixture adjustment.* Turn idle adjustment screws in until valves seat lightly, then back off one turn. Do not turn in tight since this will damage valves and seats. Run engine until it reaches normal operating temperature, and use vacuum gauge (§169) to adjust screws to give highest and steadiest vacuum reading. Idle speed may need resetting after fuel-mixture adjustment is made. If

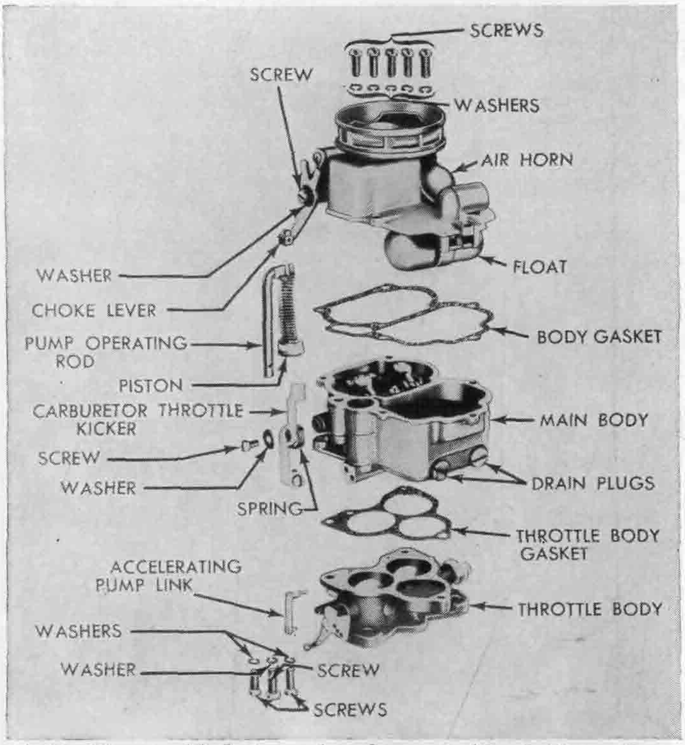


FIG. 10-26. Disassembled view of carburetor. (*Ford Motor Company*)

vacuum gauge is not available, screws may be set adjusted as explained in §185, 1 and 2, above.

2. *Idle-speed adjustment.* Idle speed is adjusted by turning the idle screw in or out. Specifications call for an idle speed of 475 to 500 rpm (or 425 rpm on cars with automatic transmission).

3. *Accelerating-pump stroke.* Accelerating-pump stroke is adjusted by shifting the pump link from one to another of the three holes in the throttle lever (see §171).

4. *Float level.* Float level is checked by removing the air horn and holding it upside down so that a gauge can be placed on the flange surface of the air horn to measure the distance from this surface to the bottom of the float (not soldered seam). The distance should be 1.322 to 1.353 inches and is adjusted by bending the float-lever arm.

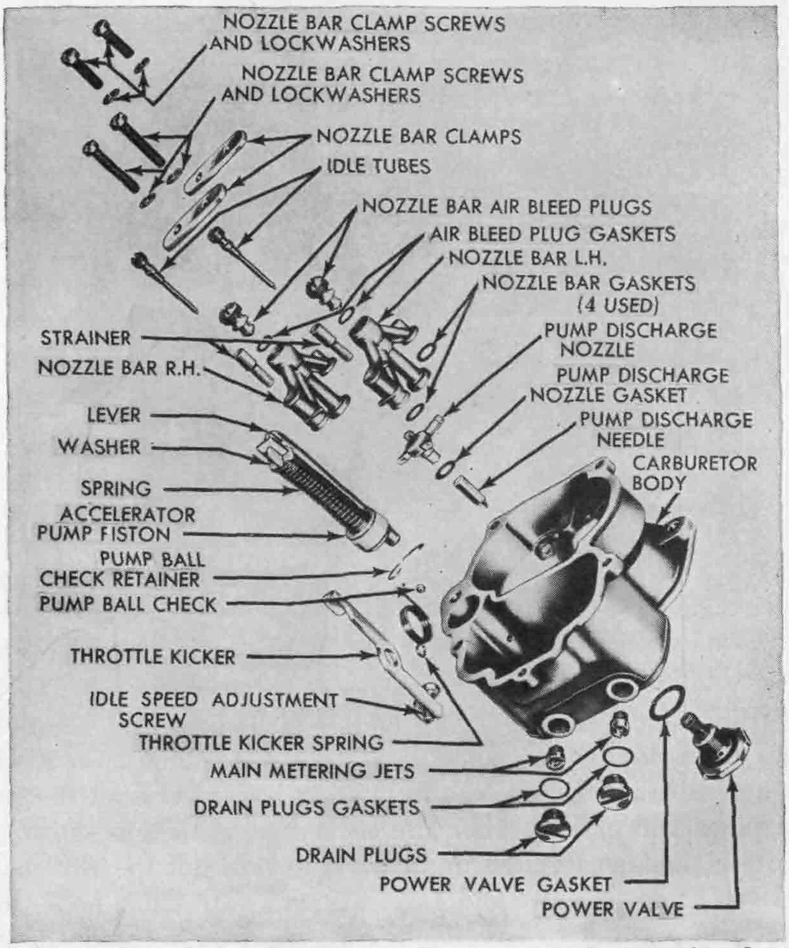


FIG. 10-27. Main body of carburetor in disassembled view. (*Ford Motor Company*)

§190. Disassembly of carburetor shown in Fig. 10-25 Be very careful about dirt during carburetor overhaul. Remember that a tiny particle of dirt in a nozzle or fuel passage may throw the carburetor action off (see §148). Do not remove the throttle plates and shaft and choke plate and shaft unless they are damaged, as it is hard to reinstall these parts correctly.

1. *Disassembling carburetor* (refer to Fig. 10-26). Remove choke lever and carburetor throttle kicker by taking off screws and washers. Disconnect and remove accelerator-pump link. Separate air horn, main body, and throttle body by removing screws and washers. Lift accelerator-pump assembly from main body.

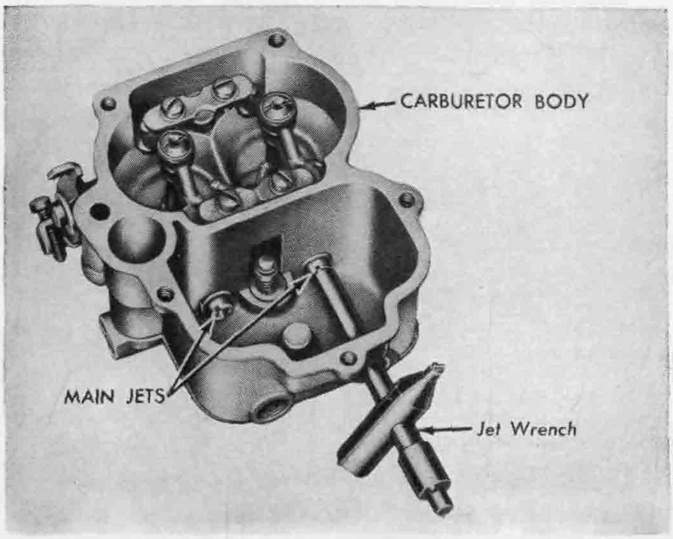


FIG. 10-28. Using jet wrench to remove main jets. (*Ford Motor Company*)

2. *Disassembling main body* (refer to Fig. 10-27). Remove screws from nozzle-bar clamps, and take out clamps, pump discharge nozzle, and nozzle bars from main body. Take out the two drain plugs and gaskets. Then use special jet wrench as shown in Fig. 10-28, and go through drain holes to take out the two main jets. Remove power valve and gasket. Bend a wire into a hook, and extract pump check ball retainer. Turn main body upside down, and catch ball check and pump discharge needle.

3. *Disassembling air horn* (refer to Fig. 10-29). Disassemble air horn by removing the float-lever shaft, float, and needle valve. Use jet wrench to unscrew needle-valve seat. If necessary, take out choke-plate screws and remove choke plate and shaft.

4. *Disassembling throttle body* (refer to Fig. 10-30). The throttle body has only a few parts that can be taken off, including the idle fuel adjustment needles that can be backed out and the throttle plates and shaft. The plates should not be removed unless they are damaged and require replacement.

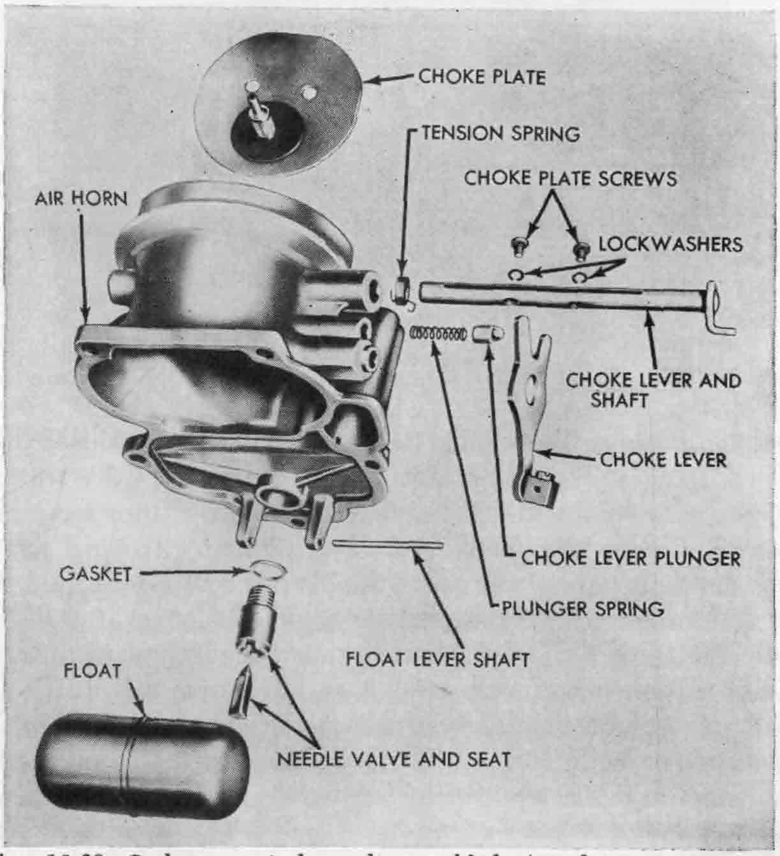


FIG. 10-29. Carburetor air horn disassembled. (*Ford Motor Company*)

5. *Inspection of parts.* Section 176 covers general overhaul instructions and explains how to clean and inspect carburetor parts. Pay special attention to the feed holes in the air horn that discharge fuel into the air stream to make sure that they are not clogged with gum or varnish. Jets and valves that are worn should be replaced. Discard old gaskets, and use new gaskets from the gasket or overhaul kit for the carburetor.

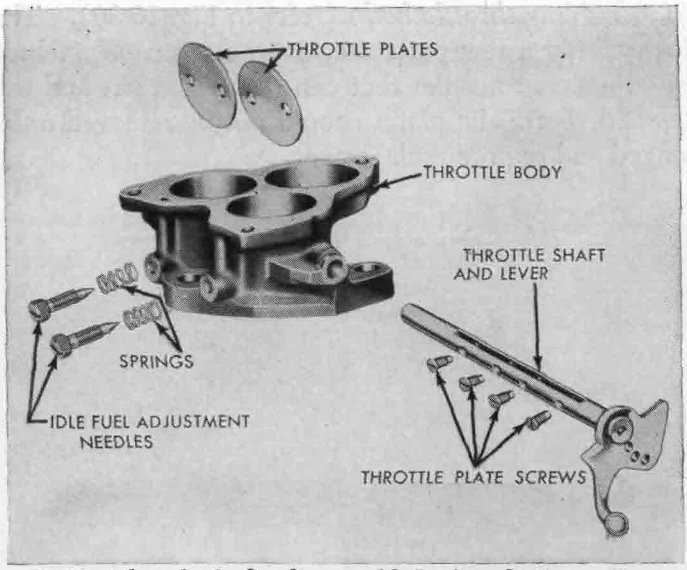


FIG. 10-30. Throttle body disassembled. (*Ford Motor Company*)

§191. Reassembly Essentially, reassembly is the reverse of disassembly. To assemble the air horn, install the needle-valve seat and new gasket. Replace the choke plate and shaft, if they have been removed. Center the plate, and then tighten attaching screws. Work the shaft to make sure that the plate is centrally located, and then stake screws lightly so that they will not loosen. Install float needle valve and float, and adjust float as already explained. Install main jets, drain plugs, and gaskets. Install power valve with new gasket, and place the pump discharge needle, nozzle, and new gasket in main body. Put four nozzle-bar gaskets in place, place two nozzle bars in position with air bleeds close to the pump discharge nozzle, and attach with nozzle-bar clamps. The two long screws are to be put on the pump discharge side. Install pump check ball and retainer and accelerator pump.

After replacing throttle plates and shaft (if they have been removed) and making sure they are centered in the barrels, tighten screws and stake them in place. Replace adjustment needles and springs.

Attach throttle body and air horn to main body with screws and lock washers, using new gaskets. Attach choke lever and throttle kicker with screws and flat washers.

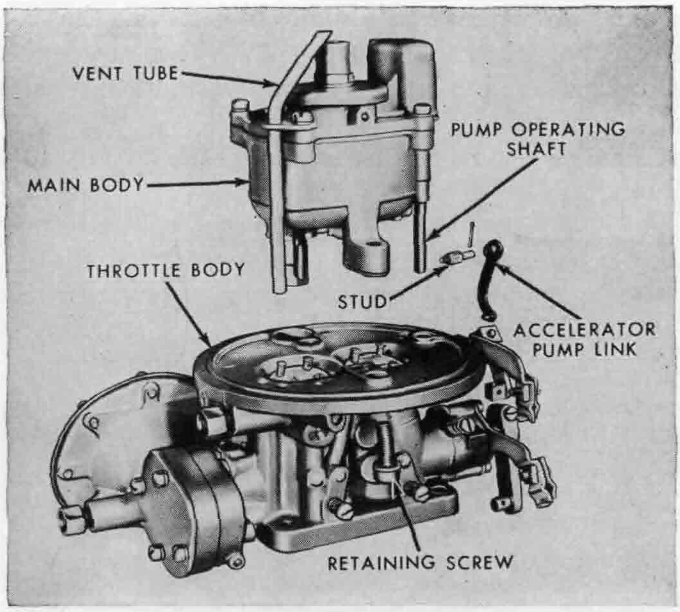


FIG. 10-31. Type of carburetor on which air cleaner is mounted to surround main body, with main body and throttle body separated. (*Ford Motor Company*)

§192. Adjustments on carburetor shown in Fig. 10-31 This carburetor was described in detail in §92 and is illustrated in Figs. 5-30 to 5-33. Adjustments are required on idle fuel mixture, idle speed, accelerator-pump stroke, and fuel level. Adjustments on idle fuel mixture, idle speed, and accelerator-pump stroke are identical to those for the carburetor described above (see §189). The fuel-level check is made by removing the air cleaner and main-body cover plate and checking the fuel level with a special gauge. The gauge measures the distance from the flange to the fuel in the float bowl. Adjustment is made by bending the float-lever tab to raise or lower the float.

§193. Disassembly of carburetor shown in Fig. 10-31 Be very careful about dirt during carburetor overhaul. Remember that a particle of dirt can change the carburetor action (§148). Do not remove throttle or choke plates unless it is necessary, since they are hard to replace properly.

1. Separate main and throttle bodies by removing the accelerator-pump-link cotter pin and removing link. Then unscrew link pin from pump shaft, and take out two screws and lock washers holding bodies together.

2. Disassemble main body as follows (refer to Fig. 10-32). Re-

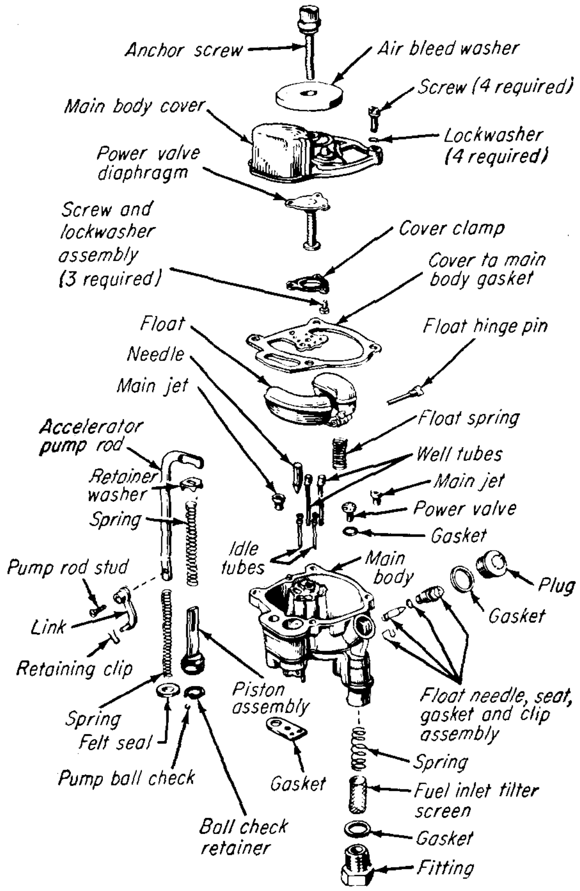


Fig. 10-32. Main body disassembled. (*Ford Motor Company*)

move anchor screw, washer, four main-body-cover attaching screws, and cover. Take power-valve diaphragm and rod from cover, if necessary, by removing three screws and retainer. Remove the main-well tubes, main jets, and idle jet assemblies with special jet tool (see Figs. 10-33 and 10-34).

3. Disassemble throttle body by removing idle-fuel-adjustment

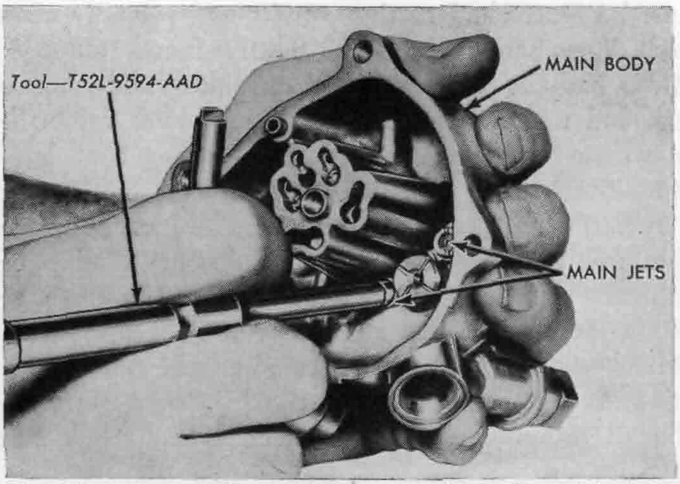


FIG. 10-33. Using jet wrench to remove main jets. (*Ford Motor Company*)

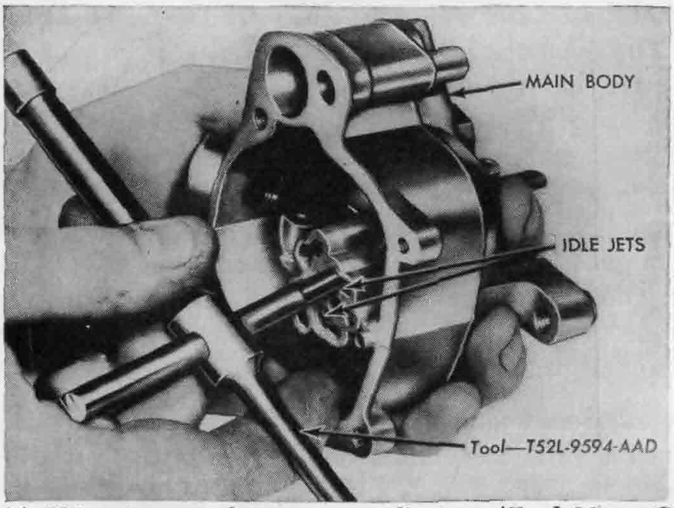


FIG. 10-34. Using jet wrench to remove idle jets. (*Ford Motor Company*)

needles and springs. If necessary, the throttle plates and shaft may be removed by filing off tips from screws and removing screws. Choke plate may be removed in the same manner.

4. Inspect all parts. Parts should be cleaned and inspected as noted in §176 and §190, 5.

§194. Reassembly of carburetor Essentially, reassembly is the reverse of disassembly. If throttle choke plates have been removed, they must be reattached to their shafts and properly centered in the barrels. Then screws should be tightened and staked lightly in place. Main body is reassembled by installing idle jet assemblies, main jets, and main-well tubes. Then the power valve should be installed with a new gasket. Install float spring, float, and needle valve, and attach float with hinge pin. Install accelerating-pump piston, operating rod, and discharge needle. Attach power-diaphragm assembly in cover, making sure that edge of diaphragm can be seen all the way around under the retainer. This guards against leakage. Use new gasket and attach cover. Then install main body on throttle body, using a new gasket. Be sure that the main fuel tubes enter the small holes in the distribution rings on the choke shaft. Install retaining screws, accelerator-pump link stud, link, and cotter pin.

§195. Overhauling four-barrel carburetors Several manufacturers supply four-barrel carburetors such as are illustrated in Figs. 5-21 to 5-25. This type of carburetor, also called a quadrijet carburetor, is used on a number of late-model automobiles. It is particularly adaptable to the V-8 engine. While the different models and makes of four-barrel carburetors are similar in operation, they vary in construction and thus require different adjustment, disassembly, and reassembly procedures. The typical procedure described below applies, in general, to the type of Carter carburetors used on Buick, Cadillac, Oldsmobile, and other automobiles with V-8 engines. Be sure to refer to the manufacturer's service manual before attempting to service or adjust other models of four-barrel carburetor.

§196. Adjustments (four-barrel unit) Adjustments on this unit are made on the float assemblies, accelerator pump, metering rods, vapor vent (antipercolator), fast idle, unloader, and lockout. Adjustment procedures follow.

1. *Float adjustments.* Three adjustments are required on the floats; horizontal, vertical, and drop. Float-bowl cover must be removed before these adjustments can be made. Gasket must be off. To remove gasket, take out float hinge pins and remove float assemblies. Then reinstall float assemblies with pins.

a. Horizontal float adjustment is made by turning cover upside down and positioning special gauge as shown in Fig. 10-35.

Sides of floats should just clear vertical uprights of gauge. Bend float arms to adjust.

b. Vertical float adjustment is made by bending center parts of float arms until floats just clear horizontal part of gauge (Fig. 10-35).

c. Float drop is adjusted by turning cover upright and measuring distance floats drop from machined face of cover. The specifications and measuring points vary with different carburetors. On one, distance between free inner ends of floats and cover should be ¾ inch. On another, distance is measured between lowest point of float and cover; distance should be $1\frac{15}{16}$ inches for primary floats and 2 inches for secondary floats.

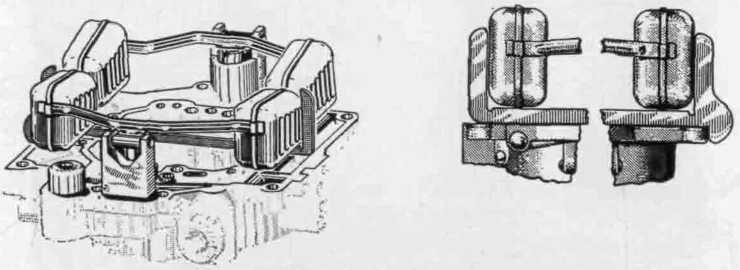


FIG. 10-35. Horizontal and vertical float adjustments. (*Oldsmobile Division of General Motors Corporation*)

Adjustment is made by removing float assembly and bending the small tang that contacts the float needle seat. Bend tang toward seat to reduce drop, away from seat to increase drop.

2. *Accelerator-pump adjustment.* Back out throttle stop screw and fast-idle screw until throttle valves are fully seated in their bores. Remove dust cover and gasket. Place straightedge across dust-cover boss and note whether upper end of pump arm is parallel with straightedge. If it is not, bend pump connector rod at the lower end (where it has a right-angle bend).

3. *Metering-rod adjustment.* With idle screw backed out so that throttle valves are fully seated, loosen clamp screw in metering-rod lever, and then push down on metering-rod link until rods bottom in carburetor bowl. Now, revolve metering-rod arm until the finger on the arm contacts the lip on the link, and tighten clamp screw.

4. *Vapor-vent adjustment.* After pump and metering-rod adjustments are completed, and with throttle lever setscrew backed out so that throttle valves are seated in bores, note the distance between the lower edge of the vapor-vent valve and the dust cover (Fig. 10-36). If it is not 1/32 inch, remove dust cover and bend the vapor-vent arm.

5. *Fast-idle adjustments.* Three separate adjustments are required. Carburetor must be completely assembled.

a. Choke-valve adjustment is made by first loosening choke-lever clamp screw (at the choke-valve shaft) and then holding the choke valve closed. Insert a 0.020-inch feeler gauge between the tang on the fast-idle cam and the boss on the carburetor casting. Then rotate choke lever toward closed position to remove all slack from the linkage. Hold lever in this position and tighten clamp screw.

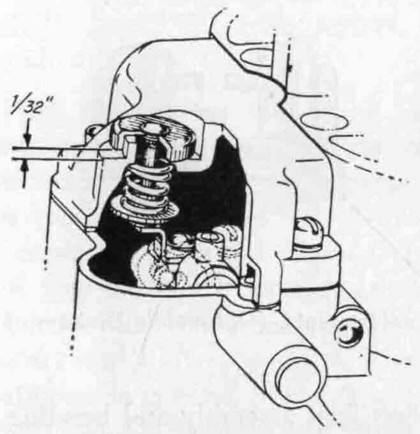


FIG. 10-36. Vapor-vent adjustment. (*Oldsmobile Division of General Motors Corporation*)

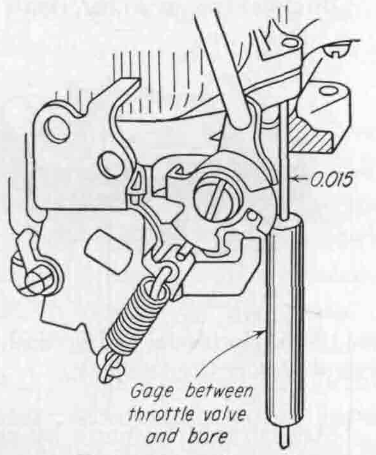


FIG. 10-37. Fast-idle adjustment. (*Oldsmobile Division of General Motors Corporation*)

b. Throttle-valve opening adjustment is made by first backing out throttle stop screw and then holding choke valve tightly closed. Then tighten fast-idle adjusting screw against the high step on the fast-idle cam until there is 0.015 inch opening between the throttle valve and primary bore of the carburetor on the side opposite the idle adjusting screws (see Fig. 10-37).

c. After carburetor is installed, run engine until it and the transmission are warm. Then connect tachometer to measure engine rpm. Put fast-idle screw on step of fast-idle cam. With air cleaner off, hold choke valve open and adjust fast-idle screw to obtain 1,600 rpm.

6. *Unloader adjustment.* The unloader will partly open the choke valve when the accelerator pedal is pushed to the floor; this permits starting in case the engine has become flooded during cranking.

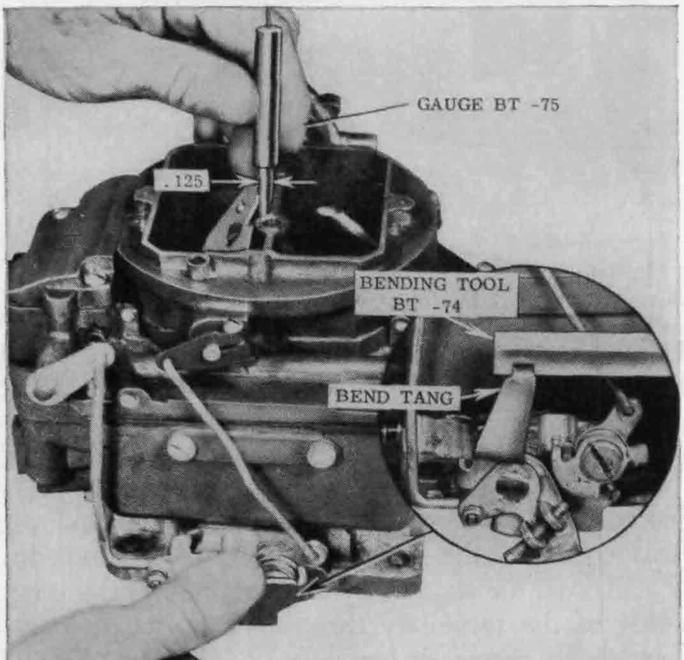


FIG. 10-38. Unloader adjustment. (*Oldsmobile Division of General Motors Corporation*)

The unloader is checked by holding the throttle lever so that valves are wide open and then checking the clearance between the upper edge of the choke valve and the inner wall of the air horn. Clearance should be ⅛ inch. It is adjusted by bending the tang on the throttle lever as shown in Fig. 10-38.

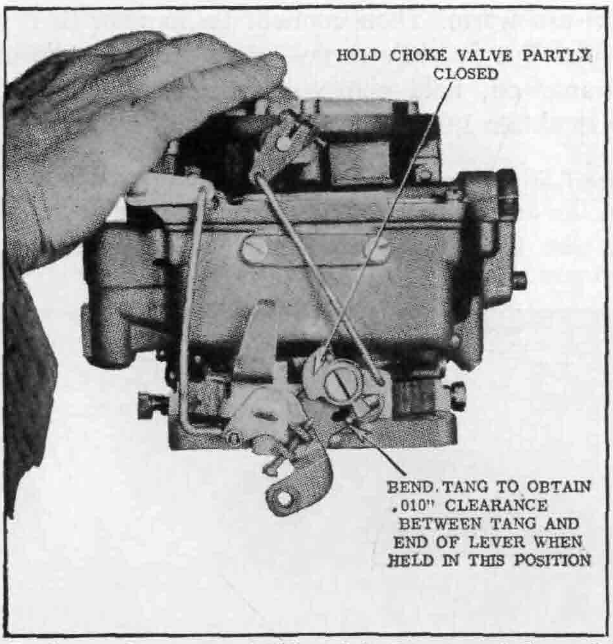


FIG. 10-39. Lockout adjustment. (*Oldsmobile Division of General Motors Corporation*)

7. *Lockout adjustment.* The lockout prevents the secondary throttle valves from opening if the choke valve (on primary side) is still closed. If the secondary throttle valves opened when the engine was cold and the choke valve closed, the engine would probably stall from the excessively lean mixture. And during cranking, opening of the secondary throttle valves would prevent the choking action so necessary for starting. The fast-idle and other adjustments described above should be made before the lockout adjustment. To make the adjustment, hold choke valve tightly closed and open primary throttle valves all the way. Note if tang on secondary throttle arm engages in notch on lockout lever to prevent secondary throttle shaft movement. Then hold choke valve wide open, and open primary throttle valves all the way. Lockout lever should now fall free to allow secondary throttle valves to open before the primary throttle valves are fully opened. If these two actions do not occur, adjust by bending tang on the secondary throttle lever to attain proper clearance (Figs. 10-39 and 10-40).

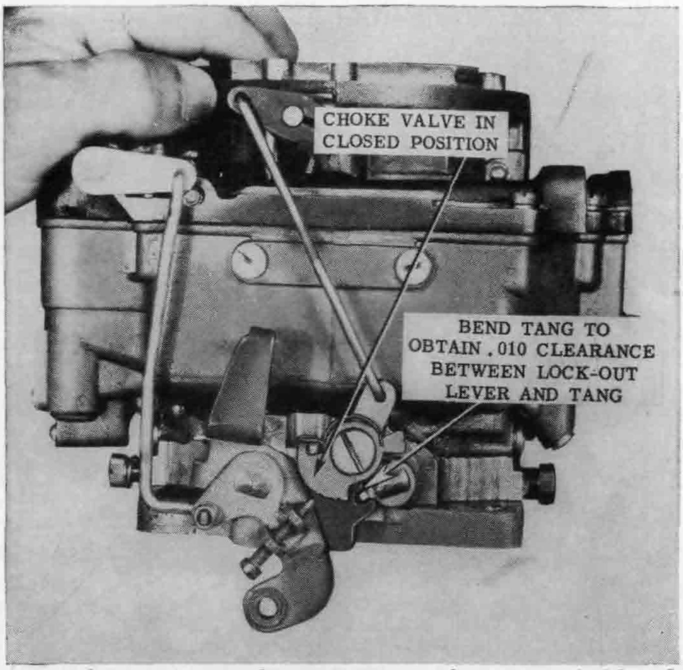


FIG. 10-40. Lockout tang and lever-clearance adjustment. (*Oldsmobile Division of General Motors Corporation*)

§197. Disassembly Be very careful about dirt during any carburetor overhaul work. It takes only a tiny particle or two of dirt to change the operating characteristics of the carburetor and possibly result in poor engine performance (see §148). Disassembly procedure can be divided into sections, according to the part of the carburetor being disassembled.

1. *Disassembly of air horn (bowl cover) (see* Fig. 10-41)

a. Remove the following parts: gasoline inlet fitting, screen, and gasket assembly; throttle connector rod; choke connector rod; dust cover and gasket; choke lever (from choke shaft); choke valve (after filing off staked ends of the two attaching screws); choke housing, gasket, and baffle plate (after taking out three screws and retainers). Then proceed as follows.

b. Rotate choke shaft to lift piston from housing and remove shaft.

c. Remove piston housing by taking out three screws.

d. Remove pin spring from accelerator-pump connector link.

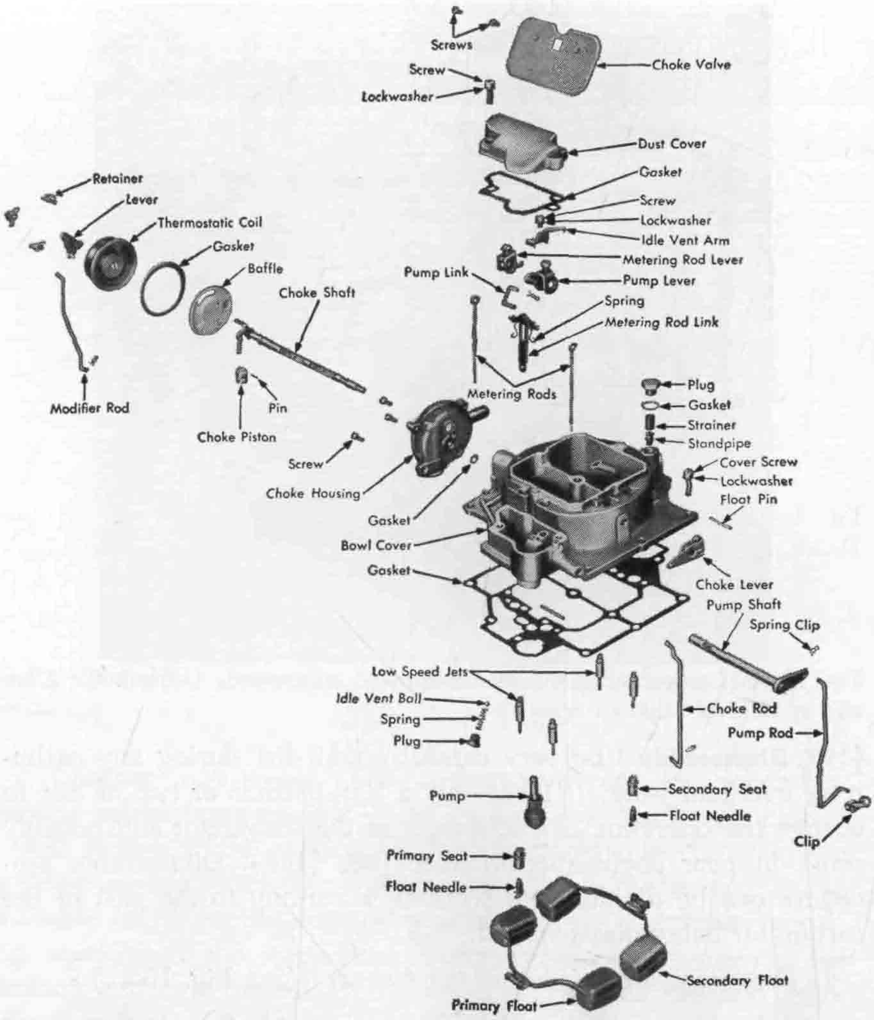


FIG. 10-41. Disassembled view of bowl cover. (*Cadillac Motor Car Division of General Motors Corporation*)

e. Slide upper end of pump connector link from pump arm (see Fig. 10-42), and rotate link around lever so link can be removed.

f. Loosen screw holding pump arm to shaft. Remove atmospheric vent arm (vapor-vent arm) by taking out screw. Loosen metering-rod-arm screw. (See Fig. 10-42 for location of these screws.)

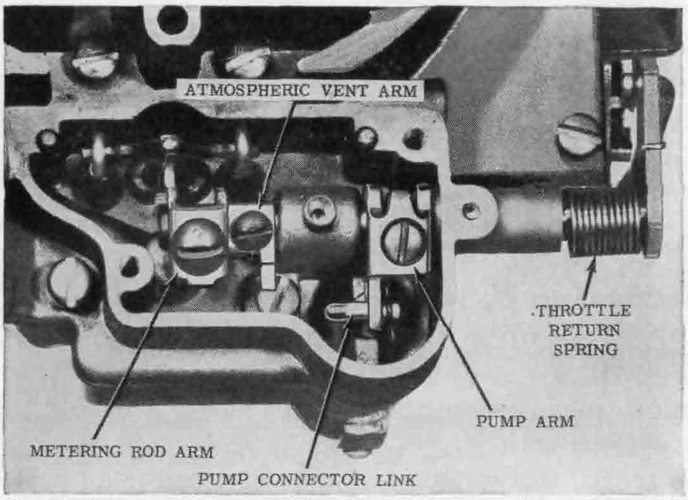


FIG. 10-42. Various parts located in the metering-rod housing. (*Oldsmobile Division of General Motors Corporation*)

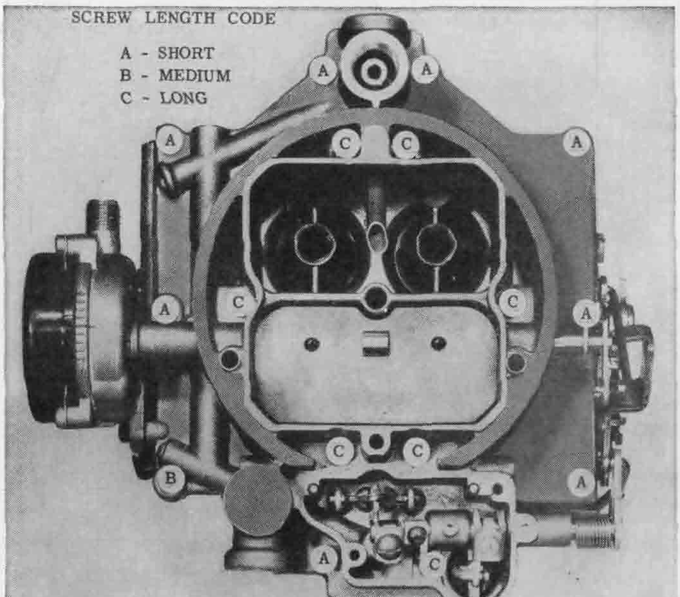


FIG. 10-43. Location of screws attaching the air horn. (*Oldsmobile Division of General Motors Corporation*)

g. Unwind throttle return spring (a piece of tag wire is handy for this).

h. Slide pump countershaft and lever assembly from carburetor. Pump arm, metering-rod arm, and the metering rods can then be lifted out.

i. Remove the 16 short, medium, and long screws attaching the cover (or air horn) to the carburetor body or bowl assembly (see Fig. 10-43).

j. Lift cover assembly off bowl assembly.

2. *Disassembly of carburetor body (bowl assembly)*

a. Remove pump guide, spring and plunger assembly, and the vacuometer spring.

b. Use special tool to remove pump inlet ball retainer from the bottom of the pump cylinder.

c. Remove pump discharge nozzle housing and gasket by taking

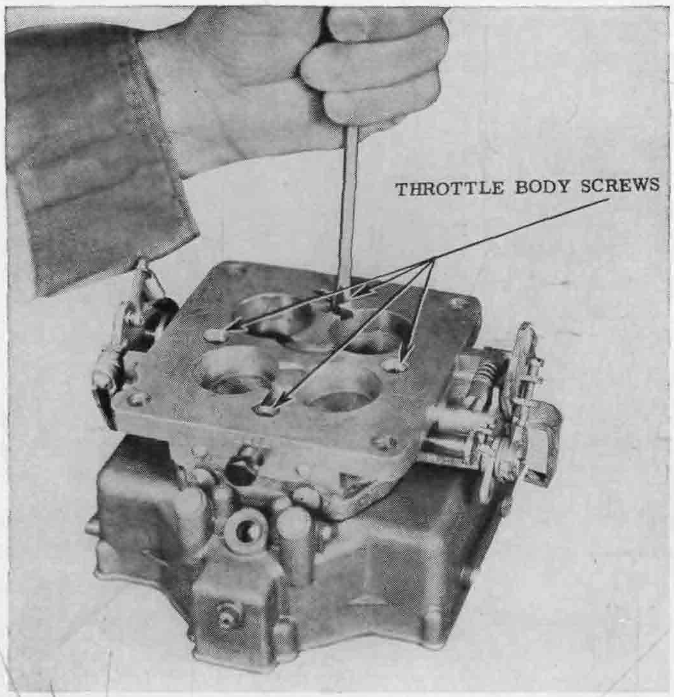


FIG. 10-44. Removing screws attaching the air horn. (*Oldsmobile Division of General Motors Corporation*)

out screw. Turn carburetor over and remove small pump discharge needle (brass).

d. Remove passage screw plug.

e. Remove primary and secondary metering-rod jets (two each). Do not mix these, as they are of different sizes!

f. Remove two low-speed jets.

g. Loosen four screws attaching throttle body to carburetor bowl (Fig. 10-44), and separate body from bowl. Remove gasket.

3. *Disassembly of air horn (or cover).* Remove two float assemblies by taking out the hinge pins. Remove needles and needle seats. Mark or group parts so that the primary and secondary parts are not mixed.

Caution: Do not mix the needles and seats!

Take off vacuum piston and link, and remove gasket from air horn.

4. *Disassembly of throttle body.* Remove idle adjusting screws (on primary side only on many models), idle-port rivet plugs, fast-idle-cam screw and cam assembly, and the connector rod linking primary and secondary throttle shafts (by taking off springs

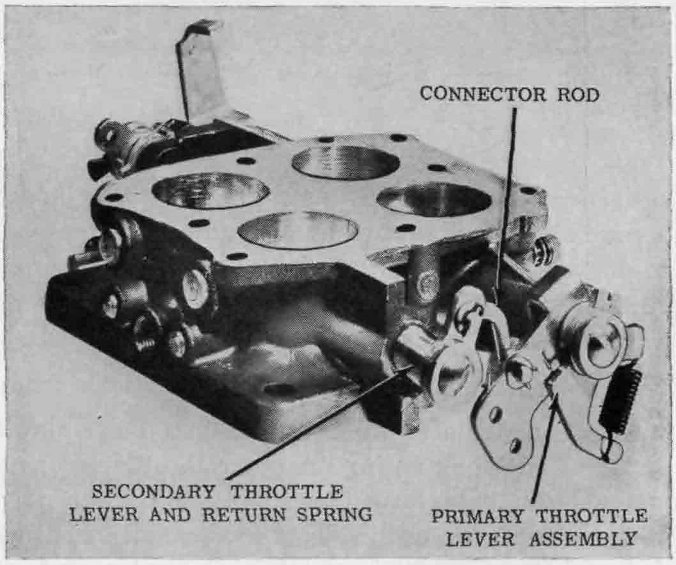


FIG. 10-45. Throttle-body-lever details. (*Oldsmobile Division of General Motors Corporation*)

and washers). See Fig. 10-45. Then remove other parts from throttle shafts (springs, screws, and levers). Note their relationship carefully, so that you will be able to replace them in same position.

5. *Inspection of parts.* Refer to §176 for details of overhaul and parts-inspection procedures.

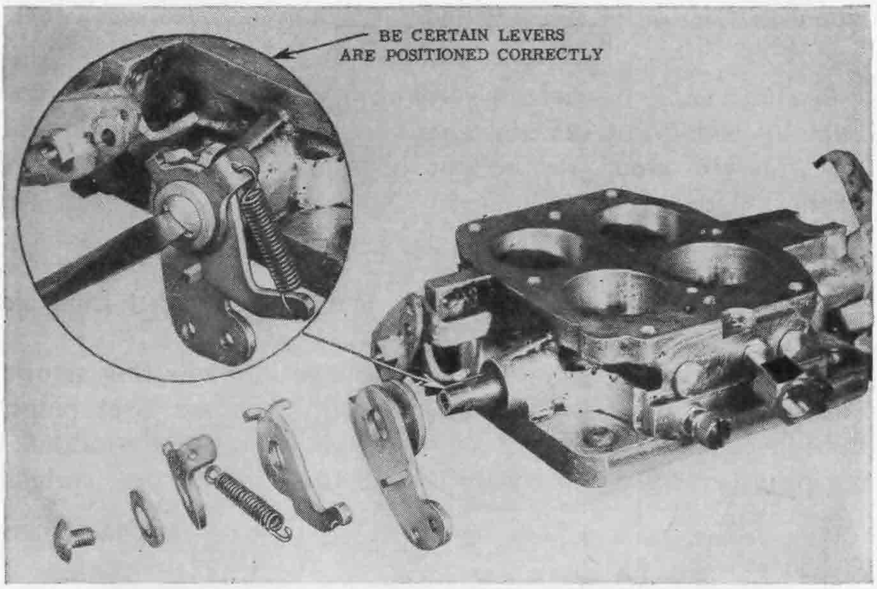


FIG. 10-46. Installing primary throttle levers. (*Oldsmobile Division of General Motors Corporation*)

§198. Carburetor reassembly 1. *Assembling throttle body.* Install new idle-port plugs. Put springs on idle adjusting screws and turn screws in *finger-tight.* Back off one turn. Do not tighten more than finger-tight, or you will damage screw tips or seats. Install secondary throttle-return spring and lever. Wind spring one-half turn with tag wire. Continue as follows.

a. Install primary shaft thrust washer and inner throttle-shaft arm and dog. Hook spring on outer throttle lever and shaft dog, and install outer lever (see Fig. 10-46).

b. Use flat washers on each side of levers, and install connector rod.

c. Open throttle valves, and install fast-idle-cam assembly as shown in Fig. 10-47. Make sure tang on choke lever is inserted under spring on fast-idle cam.

d. Put new gasket on carburetor bowl, and attach throttle body to bowl with four screws and lock washers. Make sure gasket lines up with vacuum passage.

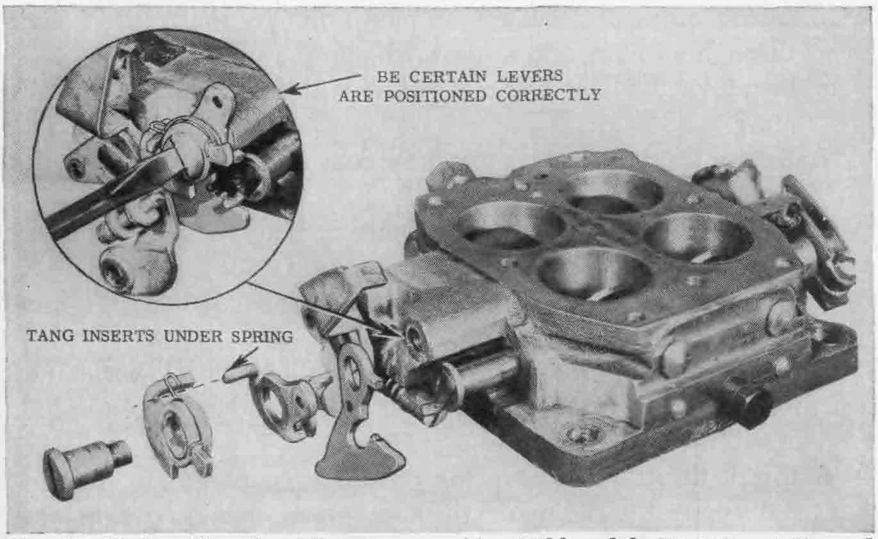


FIG. 10-47. Installing fast-idle-cam assembly. (*Oldsmobile Division of General Motors Corporation*)

2. *Assembling carburetor body*

a. Install primary and secondary metering-rod jets. The primary jets have the large holes. Do not mix primary and secondary jets!

b. Install two low-speed jets (primary side).

c. Install steel pump inlet ball check and retainer, pump passage screw plug, brass pump discharge check needle (point down), pump discharge nozzle gasket, nozzle assembly, and attaching screw. Install vacuometer spring.

3. *Assembling air horn*

a. Install primary and secondary float needle seats. Do not mix these! Needles and seats are factory-matched and must not be interchanged.

b. Temporarily install float assemblies with needles, but do not put gasket on. Check float horizontal and vertical adjustments and drop, as already explained. Then take off float assemblies, and install gasket.

c. Attach pump-arm link in outer hole of pump-arm and screw assembly, and install spring to retain it.

d. Install spring and guide over pump-plunger shaft. Insert shaft through air horn, and fasten with pump-arm link.

e. Install vacuometer link and piston with lip on link toward air horn.

f. Reinstall primary and secondary float assemblies with needles attached.

g. Place air-horn assembly on carburetor body, making sure that the vacuometer piston and the pump plunger enter their proper bores. Attach with 16 screws (see Fig. 10-43). Tighten evenly and in sequence.

h. Install metering rods. Catch rod spring loop with lower end of rod as rod is inserted and twist eye of rod onto piston-link assembly.

i. Install throttle return spring on pump countershaft; then install shaft by sliding it through pump operating arm and metering-rod arm. Make sure metering-rod operating arm is in slot in the vacuometer piston link. Tighten pump-arm screw.

j. Place washer on lower end of throttle connector rod, install rod in throttle lever, and pump countershaft lever. Attach with spring and clip at bottom and with pin spring at top. Wind throttle return spring one turn.

k. Install atmospheric vent arm.

l. Install new vacuum-passage seal in choke housing, and attach housing.

m. Install choke shaft with piston, guiding piston into cylinder in housing and then rotating shaft so that piston enters.

n. Put choke valve on shaft (C on top), center it, and install screws.

o. Put baffle plate in choke housing, and install choke cover with thermostatic spring. Set at *index* and retain with three screws and clips.

p. Install choke operating lever on shaft, and tighten screw just enough to hold it. Install choke connector rod in choke operating lever; retain lower end of rod with pin spring.

q. Make adjustments as already described (§196).

§**199. Carburetor installation** Examine the carburetor gasket, and make sure it is in perfect condition. Replace it if you have any doubt as to its condition. Put carburetor into position on intake manifold, and attach with nuts or bolts. Connect fuel line and distributor vacuum-advance line to carburetor, using two wrenches as necessary to avoid damage to the lines or couplings (§155). Connect wires to switches and other electric controls (where present). Make idle-speed, idle-mixture, and other adjustments as already explained. Install air cleaner.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You have just completed a chapter on one specialized automotive service, carburetor overhaul and repair. It may be that you will not have a great deal to do with carburetors when you work in the service shop. Nevertheless, it will help you in your other work to know how typical carburetors are constructed, how they operate, and what services they require. The following checkup will help you test yourself on how well you remember the material you have just covered on carburetor overhaul. If you are not sure of an answer, reread the pages that will clarify it for you.

Unscrambling Carburetor Trouble Causes

There are two lists below. One is headed Trouble and the other is headed Cause. Note that the causes are more numerous than the troubles. There usually can be several causes of any particular trouble. To unscramble the lists, take each item in the Trouble list, and write it down in your notebook. Then write after it the items you select from the Cause list that could cause the trouble. After each trouble, a number is given: this is the number of items you should select from the Cause list that could cause the trouble. Note that a cause may appear more than once since a cause can lead to more than one trouble. The lists below are not intended to be all-inclusive; they are merely some of the more common troubles and trouble causes.

Trouble	*Cause*
excessive fuel consumption (4)	throttle cracker misadjusted
	defective choke
lack of power (4)	clogged jets or nozzles
	choke valve closed
failure to start unless primed (3)	high float level
	worn jet or nozzles
hard starting (engine warm) (2)	stuck check valve
	low float level
	clogged jets or nozzles
	stuck metering rod or power piston
	dirty air filter
	air leaks into manifold
	clogged fuel filter

Service Procedures

In the following, you are asked to write down carburetor troubles, service cautions, or overhaul procedures. Write them in your notebook.

1. Make a list of troubles that could result from causes in the carburetor.
2. Make a list of typical carburetor adjustments and describe briefly how to make these adjustments.
3. Describe a typical carburetor-removal procedure.
4. List the main steps in carburetor overhaul.
5. List the cautions to be observed in carburetor repair work.
6. Prepare detailed disassembly, inspection, reassembly, and adjustment procedures on one or more carburetors. If possible, prepare these by using actual carburetors along with the carburetor manuals that apply to them. The best way to do this is to follow the procedure in the manual, step by step, and write down each step as you do it. You will probably wish to write the procedure down on separate sheets of paper first and then copy it into your notebook. This will keep your notebook clean.

SUGGESTIONS FOR FURTHER STUDY

Examine various carburetors and carburetor manuals in the shop. If possible, observe a carburetor specialist at work overhauling carburetors. Note how he does each step, the special tools he uses, the manuals he refers to for specifications, part numbers of new parts or repair kits he needs, and the adjustments he makes. Handle and overhaul carburetors if you can. Study all the carburetor manuals you can find, and note the construction of the different types of carburetors and the procedures used to overhaul and adjust them.

11: Engine lubricating systems

THIS CHAPTER discusses friction as it is related to engine operation and describes the various types of friction. It discusses the different types of lubricating systems used in engines to reduce friction and the different kinds of bearings used between moving surfaces in the engine.

§200. Friction Friction is the resistance to motion between two bodies in contact with each other. If you put this book on a table, you would find that it takes a certain amount of force to push it across the table top. This force overcomes the friction. If you put a second book on top of the first book, you would find that you would have to push harder to move the two books. The more weight you added, the harder you would have to push. Thus friction, or resistance to motion, increases with the load. In the engine the load between moving surfaces (in the bearings) may be well above 1,000 psi (pounds per square inch). This means that friction could be quite high. However, the lubricating oil keeps the friction at a relatively low value, as explained in following sections. Actually, friction can be divided into three classes; *dry, greasy,* and *viscous.*

§201. Dry friction Dry friction is the friction, or resistance to relative motion, between two solids. If a rough board is dragged across a rough floor, a certain pull is required. The amount of pull depends on the roughness of the surfaces and the weight of the board. For example, suppose you found that it took a pull of 10 pounds to drag a rough board across a rough floor. If you smoothed off the floor and board with sandpaper, you might find that it would then take only 5 pounds to drag the board across the floor. This gives you a clue to what dry friction is. It is considered to be caused by surface irregularities that catch against each other. Even objects machined to extreme smoothness have slight microscopic irregularities that cause resistance to relative motion, or friction. Thus even smooth, hard-metal surfaces that have relative motion under load with dry friction would soon wear. The tiny irregularities would catch on each other and tear off metal particles. These particles would then gouge out pits and scratches in the moving surfaces. Soon, the metal surfaces would be very rough and bigger particles would be broken off. The friction and wear would go up rapidly. In addition, considerable amounts of heat would be produced by the rubbing and gouging action. In fact, enough heat might result to cause the metal to melt in spots. When this happens, the two moving surfaces would momentarily weld in the melted spots; that is, there would be an actual joining of the two metal surfaces by small welded spots. With further relative movement, these welds would break, making the surfaces still rougher.

This sort of thing actually happens in machines. For example, under certain conditions, the piston rings in an engine cylinder weld (in small spots, of course) to the cylinder walls. These welds break as the rings continue to move, leaving gouged-out spots in the rings and walls.

§202. Greasy friction Greasy friction is the friction between two solids that have been coated with a very thin film of oil (and thus have what is called *borderline* lubrication). The nature of greasy friction is not very well understood. It is assumed that the film of oil fills the surface irregularities of the solids so that the two moving surfaces are almost perfectly smooth. When greasy friction exists, the resistance to motion between surfaces is much less than with dry friction. In automotive engines, greasy friction may exist in bearings and between piston rings and cylinder walls when the engine is first started. At this time, most of the lubricating oil may have drained from the surfaces so that only a thin film remains. After the engine has been started and the lubrication system has gone to work, the surfaces will be supplied with more oil. But before this happens, the surfaces have only greasy friction. With greasy friction, resistance to motion is less than with dry friction, but wear will still take place at a relatively fast rate (when compared with wear during full lubrication).

§203. Viscous friction "Viscosity" is a term that refers to the tendency of liquids, such as oil, to resist flowing. A heavy oil is more viscous than a light oil; it flows more slowly. Water has a relatively low viscosity; it flows easily. Viscous friction is the friction, or resistance to relative motion, between adjacent layers of liquid. As applied to machines, viscous friction occurs during relative motion between two lubricated surfaces (Fig. 11-1). Figure 11-1 shows, in greatly exaggerated view, an object *W* moving over a stationary object, the two being separated by lubricating oil. The oil is shown in five layers, *A* to *E*, for simplicity. (Actually, we are simplifying the entire explanation so that the theory of viscous friction can be understood more easily.)

In the illustration, layer *A* adheres to the moving object (*W*) and moves at the same speed as *W*, as indicated by the arrow. A layer of oil (*E*) adheres to the stationary object and is therefore stationary. Thus, there must be relative motion between the layers of

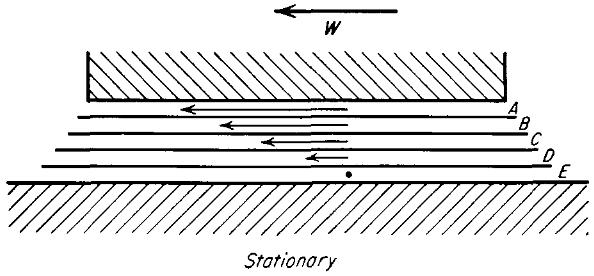


FIG. 11-1. Viscous friction is the friction between layers of liquid moving at different speeds or, in the illustration, between layers *A*, *B*, *C*, *D*, and *E*.

oil *A* and *E*. This is visualized as a slippage, or relative movement, between many layers of oil that are between layers *A* and *E*. The nearer a layer is to the stationary layer, the less it moves. This is shown by the shorter and shorter arrows in layers *B*, *C*, and *D*. Essentially, then, the friction is between a great number of oil layers. There must be slippage between the layers, and it requires force to make the slippage occur.

§204. Theory of lubrication We have already mentioned some of the things that happen during lubrication. The two objects in relative motion are held apart by a film, or layers, of oil. Thus, there is friction only between moving layers of oil, rather than between the actual objects. The friction between the oil layers, or viscous friction, is much smaller that that between solid objects (dry friction). Figure 11-1 shows how the layers act between two flat surfaces. Figure 11-2 shows how they might act between a rotating shaft journal and a stationary bearing. Layers of oil cling to the rotating journal and are carried around with it. These oil layers act somewhat like wedges and wedge in between the shaft journal and the stationary bearing. The wedging action actually lifts the journal off the bearing, so that the shaft weight is supported by the oil layers.

Figure 11-3 shows how the area of maximum loading, or high-pressure area between shaft and bearing, shifts around with changing shaft speed. When the shaft is at rest, the load is straight down,

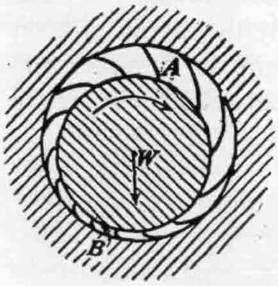


FIG. 11-2. Shaft rotation causes layers of clinging oil to be dragged around with it, so that oil moves from the wide space *A* to the narrow space *B*, and thus supports the shaft weight *W* on an oil film.

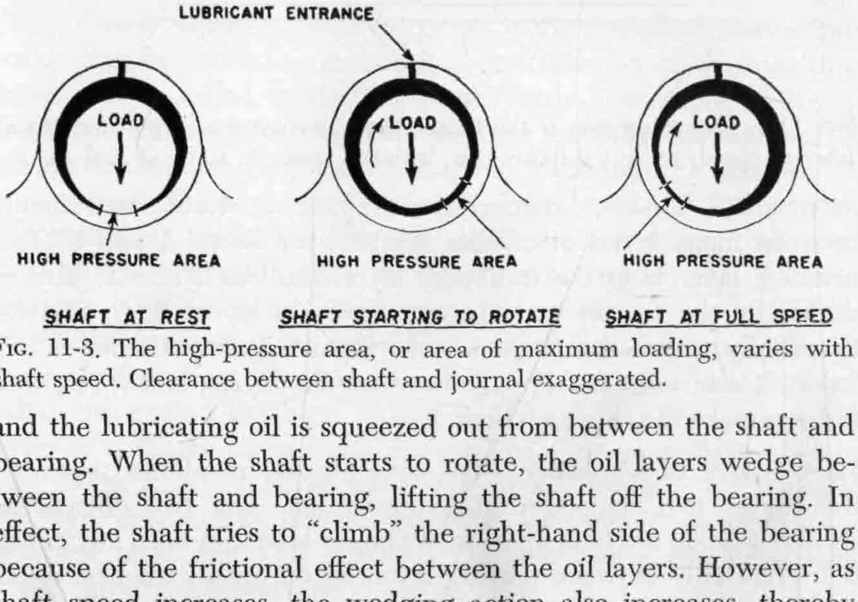


FIG. 11-3. The high-pressure area, or area of maximum loading, varies with shaft speed. Clearance between shaft and journal exaggerated.

and the lubricating oil is squeezed out from between the shaft and bearing. When the shaft starts to rotate, the oil layers wedge between the shaft and bearing, lifting the shaft off the bearing. In effect, the shaft tries to "climb" the right-hand side of the bearing because of the frictional effect between the oil layers. However, as shaft speed increases, the wedging action also increases, thereby transferring the area of maximum pressure toward the left as shown in the right-hand illustration.

§205. Types of bearings Generally speaking, the word "bearing" means anything that supports a load. So far as machines are concerned, it means anything that supports or confines an object in sliding, rotating, or oscillating motion. Machine bearings are classified as either friction-type or antifriction-type bearings. These two names are somewhat misleading, since they would indicate that one type of bearing has friction while the other does not. Actually, the friction-type bearing does have a greater amount of friction, other factors being equal. But both provide low friction between moving parts. Figure 11-4 shows graphically the differences between fric-

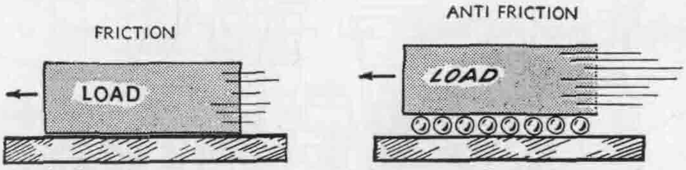


FIG. 11-4. Graphic representation of friction and antifriction bearings.

tion and antifriction bearings. In the friction bearing, one body slides over another; the load is supported on layers of oil as shown in Fig. 11-1. In the antifriction bearing, the surfaces are separated by balls or rollers so that there is rolling friction between the two surfaces and the balls or rollers.

§206. Friction bearings Friction bearings have sliding contact between the moving surfaces, as already noted. The load is actually

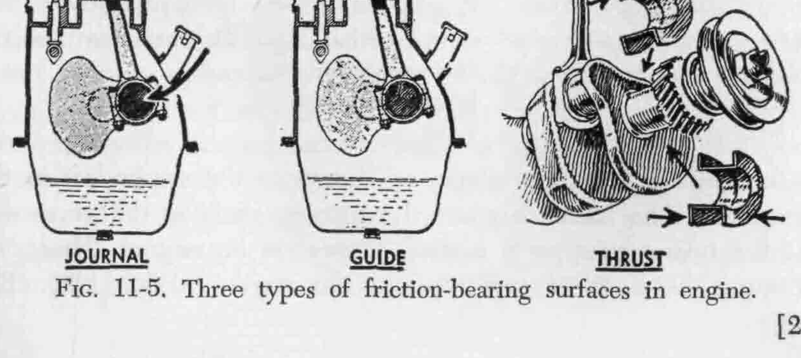


FIG. 11-5. Three types of friction-bearing surfaces in engine.

supported by layers of oil. In the automotive engine, there are three types of bearing surfaces that can be called *friction bearings.* These are illustrated in Fig. 11-5 and can be called *journal, guide,* and *thrust.* The journal-type friction bearing can be symbolized by two

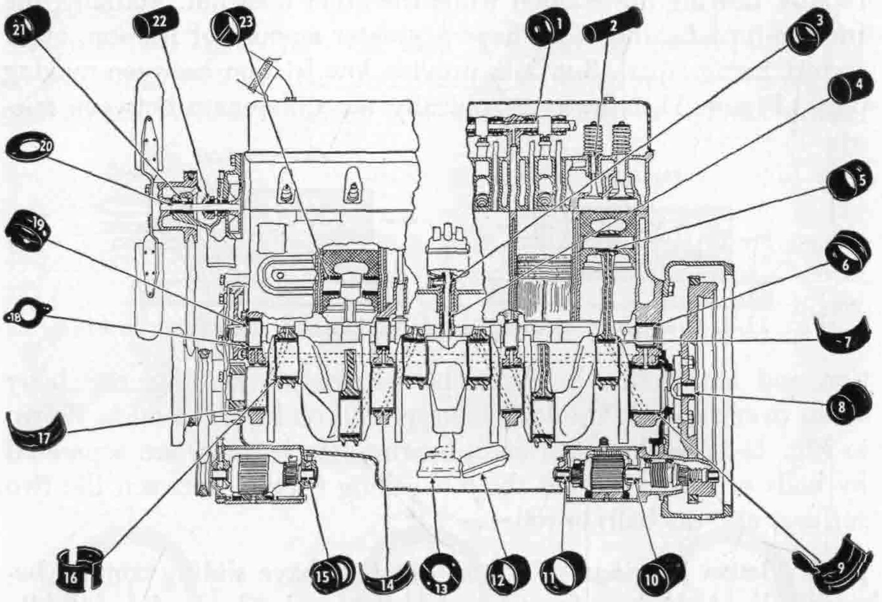


FIG. 11-6. Various bearings and bushings used in a typical engine. (*Johnson Bronze Company*)

1. Rocker-arm bushing
2. Valve-guide bushing
3. Distributor bushing —upper
4. Distributor bushing —lower
5. Piston-pin bushing
6. Camshaft bushing
7. Connecting-rod bearing
8. Clutch pilot bushing
9. Flanged main bearing
10. Starter bushing—drive end
11. Starter bushing—commutator end
12. Oil-pump bushing
13. Distributor thrust plate
14. Intermediate main bearing
15. Generator bushing
16. Connecting-rod bearing—floating type
17. Front main bearing
18. Camshaft thrust plate
19. Camshaft bushing
20. Fan thrust plate
21. Water-pump bushing—front
22. Water-pump bushing—rear
23. Piston-pin bushing

hands holding a turning shaft, as shown to the upper left in the illustration. The hands support the turning shaft in the same way that the bearing supports a shaft journal in an engine. There are numerous bearings of this type in the engine (Fig. 11-6). The crankshaft (or main) bearings, connecting-rod bearings, camshaft bearings, and piston-pin bearings are but a few. Some of these bearings are split into an upper half and a lower half. Others are of the bushing, or one-piece, type.

The bearing surface between the cylinder wall and the piston and piston rings is of the guide type. That is, the cylinder wall guides the piston up and down in its path. Of course, the piston rings also seal in compression and combustion pressure and control the oil as explained on a later page.

There is one main bearing in the engine that has thrust faces

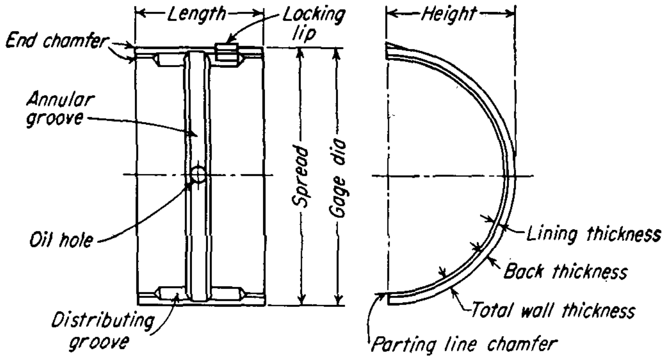


FIG. 11-7. Typical bearing half with parts named. Note oil grooves. (*Federal-Mogul Corporation*)

(right in Fig. 11-5). The thrust faces hold the shaft in position so that it does not shift endwise as it rotates. They therefore take the endwise thrust of the shaft as it attempts to move back and forth in the engine.

Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) covers engine bearings in detail.

§207. Friction-bearing lubrication In the automotive engine the friction bearings and the lubricating system are so designed as to permit a constant flow of lubricating oil across the bearing surfaces. Oil enters the clearance space between the bearing and journal, passes across the bearing face, and drains back into the oil reservoir (or crankcase) at the bottom of the engine. Many bearings have oil grooves which help spread the oil across the face of the bearing. They also serve as oil reservoirs to hold some oil for initial lubrication just after the engine is started. Figure 11-7 shows a typical bearing half with the various parts named. Note the annular and distributing grooves which are cut in the bearing face. Oil enters from the oil hole and moves around in the annular groove to the distributing grooves. Here, it is picked up by the rotating shaft journal and is carried around so that oil is distributed around the entire face of the bearing.

§208. Antifriction bearings Figure 11-8 shows three types of antifriction bearings; ball, roller, and tapered roller. The ball bearing has an inner and an outer race in which symmetrical grooves have been cut. Balls roll in these two race grooves. The balls are held

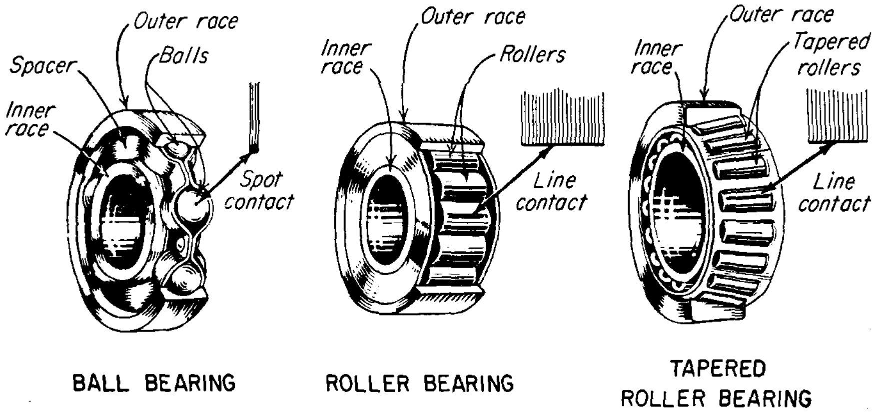


FIG. 11-8. Antifriction bearings.

apart by a spacer assembly. When one of the races is held stationary and the other rotates, the balls roll in the two races to permit low-friction rotation.

The roller bearing is similar to the ball bearing except that it has rollers (plain or tapered). The rollers roll between the inner and outer races. In the ball bearing, there is spot contact between the balls and the races. In the roller bearing, there is line contact between the rollers and races.

Antifriction bearings are usually lubricated by grease. Essentially, grease is oil mixed with a solidifying agent (§216). The solidifying agent does not directly lubricate the balls or rollers, but it does hold the oil in the bearing so that the bearing gets proper lubrication.

§209. Purpose of engine lubricating system We normally think of lubricating oil as a substance that makes possible minimum wear or low frictional loss between adjacent moving surfaces. However, the lubricating oil circulating through the engine to all moving parts requiring lubrication performs other jobs. The lubricating oil must

1. Lubricate moving parts to minimize wear.
2. Lubricate moving parts to minimize power loss from friction.
3. Remove heat from engine parts by acting as a cooling agent.
4. Absorb shocks between bearings and other engine parts, thus reducing engine noise and extending engine life.
5. Form a good seal between piston rings and cylinder walls.
6. Act as a cleaning agent.

1 and 2. Minimizing wear and power loss from friction. Friction has been discussed in some detail (§§200 to 203). The type of friction encountered in the engine is normally viscous friction, that is, the friction between adjacent moving layers of oil. If the lubricating system does not function properly, sufficient oil will not be supplied to moving parts, and greasy or even dry friction will result between moving surfaces. This would cause, at the least, considerable power loss, since power would be used in overcoming these types of friction. At the worst, major damage would occur to engine parts as greasy or dry friction developed. Bearings would wear with extreme rapidity; the heat resulting from dry or greasy friction would cause bearing disintegration and failure, so that connecting rods and other parts would be broken. Insufficient lubrication of cylinder walls would cause rapid wear and scoring of walls, rings, and pistons. A properly operating engine lubricating system supplies all moving parts with sufficient oil so that only viscous friction is obtained.

3. *Removing heat from engine parts.* The engine oil is in rapid circulation throughout the engine lubrication system. All bearings and moving parts are bathed in constant streams of oil. In addition to providing lubrication, the oil absorbs heat from engine parts and carries it back into the oil pan. The oil pan in turn absorbs heat from the oil, transferring it to the surrounding air. The oil thus acts as a cooling agent.

4. *Absorbing shocks between bearings and other engine parts.* As the piston approaches the end of the compression stroke and the

mixture in the cylinder is ignited, pressure in the cylinder suddenly increases many times. A load of as much as 2½ tons is suddenly imposed on the top of a 3-inch piston as combustion takes place. This sudden increase in pressure causes the piston to thrust down hard through the piston-pin bearing, connecting rod, and connecting-rod bearing. There is always some space or clearance between bearings and journals; this space is filled with oil. When the load suddenly increases as described above, the layers of oil between bearings and journals must act as cushions, resisting penetration or "squeezing out," and must continue to interpose a film of oil between the adjacent metal surfaces. In thus absorbing and cushioning the hammerlike effect of the suddenly imposed loads, the oil quiets the engine and reduces wear of parts.

5. *Forming a seal between piston rings and cylinder walls.* Piston rings must form a gastight seal with the cylinder walls, and the lubricating oil that is delivered to the cylinder walls helps the piston rings to accomplish this. The oil film on the cylinder walls compensates for microscopic irregularities in the fit between the rings and walls and fills in any gaps through which gas might escape. The oil film also provides lubrication of the rings, so that they can move easily in the piston-ring grooves and on the cylinder walls.

6. *Acting as a cleaning agent.* The oil, as it circulates through the engine, tends to wash off and carry away dirt, particles of carbon, and other foreign matter. As the oil picks up this material, it carries it back to the crankcase. There, larger particles drop to the bottom of the oil pan. Many of the smaller particles are removed from the oil by oil-filter action.

§210. Source of oil Engine oil, as well as gasoline and various automobile lubricants, comes from petroleum, or crude oil. As mentioned in §102, petroleum is found in reservoirs, pools, under the ground. Evidence indicates it was formed from animal or plant sources millions of years ago. The oil is "recovered," or removed from the earth, by wells drilled down to the reservoirs.

The petroleum, as it comes from the ground, is not usable for lubricating purposes. It must first be refined. This refining process separates the petroleum into various parts, or constituents. A simplified explanation of the refining process might run like this. The petroleum is heated in an enclosed chamber, or still. As the petroleum temperature increases, the more volatile parts evaporate first (see §103). These vapors are led from the enclosed chamber through tubing to cooler chambers where they condense. These more volatile parts of the petroleum form gasoline. As the petroleum is heated to higher and higher temperatures, the less and less volatile parts form engine oil and various heavier products, including tar. Properties of gasoline are described in Chap. 7. Properties of engine oils are discussed in §211. Properties of various other automotive lubricants are considered in §216.

NOTE: LPG, or liquefied petroleum gas, is also obtained from petroleum, and it is the most volatile fraction (or part) of the petroleum, tending to turn to vapor even at atmospheric pressure.

§211. Properties of oil A satisfactory engine lubricating oil must have certain characteristics. It must have proper (1) body and fluidity, or viscosity; (2) resistance to carbon formation; and (3) resistance to oxidation.

1. *Viscosity (body and fluidity).* Primarily, viscosity is the most important characteristic of lubricating oil. Viscosity refers to the tendency of oil to resist flowing. In a bearing and journal, layers of oil adhere to the bearing and journal surfaces. These layers must move or slip with respect to each other, and the viscosity of the oil determines the ease with which this slipping can take place. Viscosity changes with temperature, since increasing temperature causes oil to thin and have a lower viscosity, while decreasing temperature causes oil to thicken and have a higher viscosity. Viscosity may be divided for discussion into two parts, body and fluidity. Body has to do with the resistance to oil-film puncture, or penetration, during the application of heavy loads. When the power stroke begins, for example, bearing loads sharply increase. Oil body prevents the load from squeezing out the film of oil between the journal and the bearing. This property cushions shock loads, helps maintain a good seal between piston rings and cylinder walls, and maintains an adequate oil film on all bearing surfaces under load.

Fluidity has to do with the ease with which the oil flows through oil lines and spreads over bearing surfaces. In some respects, fluidity and body are opposing characteristics, since the more fluid an oil is, the less body it has. The oil used in any particular engine must have sufficient body to perform as explained in the previous paragraph and yet must have sufficient fluidity to flow freely through all oil lines and spread effectively over all bearing surfaces. Late types of engines have more closely fitted bearings with smaller clearances and consequently require oils of greater fluidity that will flow readily into the spaces between bearings and journals. Such engines use oils of lower viscosity.

Temperature influences viscosity. Increasing temperature causes oil to lose body and gain fluidity, while decreasing temperature causes oil to gain body and lose fluidity. Since engine temperatures range several hundred degrees from cold-weather starting to operating temperature, a lubricating oil must have adequate fluidity at low temperatures so that it will flow. At the same time, it must have sufficient body for high-temperature operation.

2. *Viscosity ratings.* Viscosity of oil is determined by use of a viscosimeter, a device that can be used to determine the length of time required for a definite amount of oil to flow through an opening of a definite diameter. Temperature is taken into consideration during this test, since high temperature decreases viscosity while low temperature increases viscosity. In referring to viscosity, the lower numbers refer to oils of lower viscosity. SAE 10 oil is less viscous (thinner) than SAE 20 oil, for example.

3. *Resistance to carbon formation.* Cylinder walls, pistons, and rings operate at temperatures of several hundred degrees. This temperature acting on the oil films covering walls, rings, and pistons tends to cause the oil to break down or burn so that carbon is produced. Carbon formation can cause poor engine performance and damage to the engine. Carbon may pack in around the piston rings, causing them to stick in the ring grooves. This prevents proper piston-ring operation, so that blow-by, poor compression, excessive oil consumption, and scoring of cylinder walls may result. Carbon may build up on the piston head and in the cylinder head. This fouls spark plugs, excessively increases compression so that knocking occurs, and reduces engine performance. Carbon may form on the underside of the piston to such an extent that heat transfer will be hindered and the piston will overheat. Pieces of carbon may break off and drop into the oil pan, where they will be picked up by the lubrication system and will clog oil channels and lines so that the flow of lubricating oil to engine parts is dangerously reduced. A good lubricating oil must be sufficiently resistant to the heat and

operating conditions in the engine to exhibit a minimum amount of carbon formation.

4. *Resistance to oxidation.* When oil is heated to fairly high temperatures and then agitated so that considerable air is mixed with it, the oxygen in the air tends to combine with oil, oxidizing it. Since this is the treatment that engine oil undergoes (that is, it is heated and agitated with or sprayed into the air in the crankcase), some oil oxidation is bound to occur. A slight amount of oxidation will do no particular harm; but if oxidation becomes excessive, serious troubles may occur in the engine. As the oil is oxidized, it breaks down to form various harmful substances. Some of the products of oil oxidation will coat engine parts with an extremely sticky, tarlike material that clogs oil channels and tends to restrict the action of piston rings and valves. A somewhat different form of oil oxidation coats engine parts with a varnishlike substance that has a similar damaging effect on the engine. Even if these substances do not form, oil oxidation may produce corrosive materials in the oil that will corrode bearings and other surfaces, causing bearing failures and damage to other parts. Oil chemists and refineries control the refining processes and may add certain chemicals known as *oxidation inhibitors* so that engine lubricating oils resist oxidation. (Any substance added to the oil is known as an *additive.*)

5. *Foaming resistance.* The churning action in the engine crankcase also tends to cause the engine oil to foam, just as an egg beater causes an egg white to form a frothy foam. As the oil foams up, it tends to overflow or to be lost through the crankcase ventilator (§223). In addition, the foaming oil is not able to provide normal lubrication of bearings and other moving parts. To prevent foaming, antifoaming additives are mixed with the oil.

6. *Detergents.* Despite the filters and screens at the carburetor and crankcase ventilator (§223), dirt does get into the engine. In addition, as the engine runs, the combustion processes leave deposits of carbon on piston rings, valves, and other parts. Also, some oil oxidation may take place, resulting in still other deposits. As a result of these various conditions, deposits tend to build up on and in engine parts. The deposits gradually reduce the performance of the engine and speed up wear of parts. To prevent or slow down the formation of these deposits, some engine oils contain a detergent additive.

The detergent acts much like ordinary hand soap. When you wash your hands with soap, the soap surrounds the particles of dirt on your hands, causing them to become detached so that the water can rinse them away. In a similar manner, the detergent in the oil loosens and detaches the deposits of carbon, gum and dirt. The oil then carries the loosened material away. The larger particles drop to the bottom of the crankcase, but smaller particles tend to remain suspended in the oil. These impurities, or contaminants, are flushed out when the oil is changed.

7. *Viscosity index.* When oil is cold, it is thicker and runs more slowly than when it is hot. In other words, it becomes more viscous when it is cooled. On the other hand, it becomes less viscous when it is heated. In normal automotive-engine operation we do not have to be too concerned about this change of oil viscosity with changing temperature. We recognize that the engine is harder to start at low temperature because the oil is thicker, or more viscous. But until the engine is cooled to many degrees below zero, we do not have to take any special steps to start it.

Some oils change viscosity a great deal with temperature change. Other oils show a much smaller change of viscosity with temperature change. In order to have an accurate measure of how much any particular oil will change in viscosity with temperature change, the viscosity-index scale was adopted. Originally, the scale ran from 0 to 100. The higher the number, the less the oil viscosity changes with temperature changes. Thus, an oil with a VI (viscosity index) of 100 will change less in viscosity with temperature changes than an oil with a VI of 10. In recent years, special VI-improving additives have been developed which step up viscosity indexes to as much as 300. Such an oil shows relatively little change in viscosity from very low to relatively high temperature.

You could especially appreciate the significance of VI if you were operating automotive equipment in a very cold climate (say in northern Alaska). You would have to start engines at temperatures of as much as 60° below zero (92° below freezing). But once started, the engines would soon reach operating temperatures that heat the oil to several hundred degrees. If you could select an oil of a relatively high VI, then it would be fluid enough to permit starting but would not thin out (or lose viscosity) so much that lubricating effectiveness would be lost. On the other hand, an oil with a low VI would probably be so thick at low temperatures that it might actually prevent starting. But if you could start, it might then thin out too much as it warmed up.

Actually, VI is of relatively little importance in most parts of the country. Oil companies make sure that their oils have a sufficiently high VI to operate satisfactorily in the variations of temperatures they will meet.

CHECK YOUR PROGRESS

Progress Quiz 10

Once again you have the chance to check up on your progress in the book. The questions below will help you review what you have just finished reading on friction and lubrication. Answering the questions recalls to your mind the important points; this helps you remember them.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The resistance to motion between two bodies in contact is called *load* *force* *power* *friction*
2. The three classes of friction are *dry, smooth, and solid* *dry, greasy, and viscous* *dry, moist, and greasy*
3. With greasy friction, we have what is called *dry lubrication* *borderline lubrication* *viscous lubrication*
4. The friction, or resistance to relative motion, between adjacent layers of liquid is called *dry friction* *greasy friction* *viscous friction*
5. The three general types of friction bearings are *journal, guide, and thrust* *journal, shaft, and thrust* *journal, ball, and roller*
6. Three types of antifriction bearings are *sleeve, ball, and roller* *sleeve, thrust, and ball* *ball, roller, and tapered roller*
7. For discussion, viscosity can be divided into two characteristics *fluidity and body* *sealing and inhibiting* *friction and fluidity*
8. The ease with which oil flows through oil lines and over bearing surfaces is called oil *fluidity* *body* *viscosity*

9. Resistance to squeezing out of the oil from between journal and bearing is referred to in terms of oil *fluidity* *body* *volatility*
10. Generally speaking, any substance or chemical added to the oil to enhance various properties is called *an inhibitor* *an additive* *a detergent*

§212. Water-sludge formation Water sludge is a thick, creamy, black substance that often forms in the crankcase. It clogs up oil screens and oil lines, preventing normal circulation of lubricating oil to the engine parts. This can result in engine failure from oil starvation.

1. How sludge forms. Water collects in the crankcase in two ways. Water is one of the products formed during combustion. Hydrogen in the fuel unites with oxygen in the air to form H_2O, or water. Most of this water is exhausted from the engine as vapor in the exhaust gases. But when the engine is cold, some of it condenses on the cold engine parts. It then works its way past the piston rings and drops into the crankcase. Another way that water gets into the crankcase is through the crankcase ventilating system (§223). When the engine is cold, moisture in the air drawn through the crankcase by the ventilating system is apt to condense on the cold engine parts and thus stay in the crankcase.

The water that accumulates is churned up with the lubricating oil by the action of the moving parts, particularly the crankshaft. In effect, the crankshaft is a super egg beater that whips the oil and water together to form the thick, black, mayonnaiselike "goo" called *water sludge*. The black color comes from dirt and carbon in the oil.

2. Sludge-forming operation. If you drive your car for fairly long distances each time you start it, you will have little trouble with water sludge. It is true that water will collect in the crankcase for the first few miles, before the engine warms up. But as soon as the engine reaches operating temperature, the water evaporates and is cleared from the crankcase by the crankcase ventilator. However, if you drive your car only a few miles each time you start it and allow it to cool off between trips, then the engine will not get warm enough to throw off the water it has collected in the crankcase. With each short trip, more water collects. And as the water collects, it is whipped with the oil into water sludge.

Note that it is the short-trip, start-and-stop type of operation that produces sludge. And this type of operation is far more common than you might think. Studies of car operation in the United States have shown that about 38 percent of all trips are less than 3 miles in length. Another 24 percent are from 3 to 6 miles long. An additional 18 percent are from 7 to 13 miles long, and only 20 percent are more than 13 miles in length (see Fig. 11-9).

3. *Getting rid of water.* As we mentioned, if the car is driven long enough, the engine will warm up and the water will be

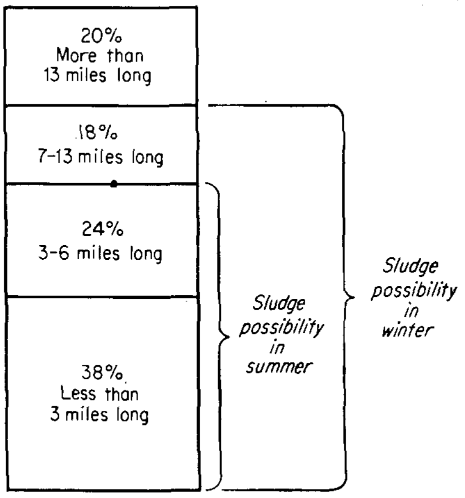


FIG. 11-9. Car-trip mileages showing percentage of short, medium, and long trips (percentages only approximate).

evaporated and carried out of the crankcase by the ventilating system. The number of miles required for this varies from car to car, and also with the weather. During winter months, the engine is colder and takes longer (more miles) to warm up. Studies have shown that during the summer it takes from 3 to 6 miles, on the average, for the engine to reach operating temperature and begin to rid itself of water. But during the winter it takes about 14 miles. When you compare these figures with the average length of trip as noted in the previous paragraph, you can see that as many as 60 percent of the car trips are too short in summer to rid the engine of water. In winter as many as 80 percent of the car trips are too short to rid the engine of water (see Fig. 11-9).

4. *Preventing sludge accumulations.* Sludge can lead to engine failure by blocking oil circulation to engine parts. Thus, it is important to prevent accumulation of sufficient sludge to cause poor oil circulation. One way of doing this, as noted above, is to take longer trips in your car. Another way is to drain the crankcase oil frequently. With frequent oil drains, the sludge never has a chance to accumulate in really damaging amounts. Section 214 discusses oil changes.

§213. Service ratings of lubricating oil We have already mentioned that lubricating oil is rated as to its viscosity by number. An SAE 10 oil is less viscous (lighter) than an SAE 20 oil. An SAE 30 oil has a comparatively high viscosity. Lubricating oil is also rated in another way, by what is called *service* designation. That is, it is rated according to the type of service for which it is best suited. There are five service ratings; MS, MM, and ML for gasoline or other spark-ignition engines, and DG and DS for diesel engines. The oils differ in their characteristics and in the additives they contain.

1. *MS oil.* This oil is for severe service and unfavorable operating conditions. It is to be used where there are special lubricating requirements for bearing-corrosion and engine-deposit control because of operating conditions or engine design. This includes:

a. Low operating temperature and short-trip, start-stop driving conditions, as found in city operation.
b. High-speed highway driving, where oil will become unusually hot, as during a summer-vacation trip.
c. Heavy-load operation, such as is typical of highway truck service.

2. *MM oil.* This oil is for medium service such as:

a. High-speed but fairly short trips.
b. Long trips at moderate speeds and summer temperatures.
c. Operation at moderate cold-air temperatures where the car is used for both long and short trips.

3. *ML oil.* This oil is for comparatively light service where most of the trips are longer than 10 miles and where no extremes of air temperature are encountered.

Caution: Do not confuse *viscosity* and *service* ratings of oil. Some people think that a high-viscosity oil is a "heavy-duty" oil. This is not necessarily so. Viscosity rating refers to the thickness of the oil; thickness is not a measure of heavy-duty quality. Remember that there are two ratings, viscosity and service. Thus, an SAE 10 oil can be an MS, MM, or ML oil. Likewise, an oil of any other viscosity rating can have any one of the three service ratings (MS, MM, or ML).

4. *DS oil.* This is an oil for lubricating diesel engines operating under the most severe service conditions such as:

a. Continuous low temperatures and light loads.
b. Continuous high-temperature, heavy-load conditions.
c. Operation on fuels of high sulfur content or abnormal volatility.

5. *DG oil.* This is an oil for lubricating diesel engines operating under comparatively light to normal conditions such as are typical of most trucking and farm-tractor operations.

§214. Oil changes We have already noted that oil should be changed periodically to get rid of the water sludge that tends to accumulate in the crankcase. But that is not the only reason for changing oil periodically. From the day that the old oil is drained and new oil put into the crankcase, the new oil begins to lose its effectiveness as an engine lubricant. This gradual loss of effectiveness is largely due to the accumulation of various contaminating substances. For instance, during engine operation, carbon tends to form in the combustion chamber. Some of this carbon gets into the oil. Gum, acids, and certain lacquerlike substances are also left by the combustion of the fuel or are produced in the oil itself by the high engine temperatures. In addition, the air that enters the engine (in the air-fuel mixture) carries with it a certain amount of dust. Even though the air filter is operating efficiently, it will not remove all the dust. Then, too, the engine releases fine metal particles as it wears. All these substances tend to circulate with the oil. As the mileage piles up, the oil accumulates more and more of these contaminants. Even though the engine has an oil filter, some of these contaminants will remain in the oil. Finally, after so many miles of operation, the oil will be so loaded with contaminants that it is not safe to use. Unless it is drained and clean oil put in, engine wear will increase rapidly.

Modern engine oils are compounded to fight contamination. They contain certain chemicals (called *additives*) which deter corrosion and foaming and help to keep the engine clean by detergent action. Yet they cannot keep the oil in good condition indefinitely. As mentioned in the previous paragraph, after so many miles of service, the oil is bound to become contaminated and it must be drained. The actual mileage varies with the type of operation. For dusty or cold-weather start-and-stop driving, the oil should be changed every 500 miles or 60 days. For "average" operation, that is, short-run, start-and-stop service on paved roads with moderate temperatures, mixed with longer trips, the oil should be changed every 1,000 miles. For open highway driving on paved roads, oil should be changed every 2,000 miles.

NOTE: Automobile manufacturers recommend that the oil be changed (along with the oil filter) and the air filter cleaned, whenever the car has been subjected to a spell of dusty driving or has encountered a dust storm. When driving in dusty conditions, the air and oil filters are apt to get clogged with dust rather quickly. This means that the oil takes on an excessive amount of dust. This dust must be removed from the engine by draining the oil, cleaning the air filters, and replacing the oil filter.

§215. Oil consumption Oil is lost from the engine in three ways: by burning in the combustion chamber, by leakage in liquid form, and by passing out of the crankcase in the form of a mist. Two main factors affect oil consumption, *engine speed* and *the amount that engine parts have worn.* High speed produces high temperature, which in turn lowers the viscosity of the oil so that it can more readily work past the piston rings into the combustion chamber, where it is burned. In addition, the high speed exerts a centrifugal effect on the oil that is feeding through the oil lines drilled in the crankshaft to the connecting-rod journals, so that more oil is fed to the bearings and subsequently thrown on the cylinder walls. Also, high speed tends to cause "ring shimmy," a condition in which the oil-control rings cannot function quite so effectively and will allow more oil to get into the combustion chamber. Then, too, crankcase ventilation (§223) causes more air to pass through the crankcase at high speed, increasing the tendency for oil to be lost in the form of mist.

As engine parts wear, oil consumption increases. Worn bearings tend to throw more oil onto the cylinder walls. Tapered and worn cylinder walls prevent normal oil-control-ring action because the rings cannot change shape rapidly enough to conform with the worn cylinder walls as they move up and down. More oil consequently gets into the combustion chamber, where it burns and fouls spark plugs, valves, rings, and pistons. Carbon formation aggravates the condition, since it further reduces the effectiveness of the oil-control rings. Where cylinder-wall wear is not excessive, installation of special oil-control rings (see *Automotive Engines*) reduces oil consumption by improving the wiping action so that less oil can move past the rings. After cylinder-wall wear has progressed beyond a certain point, the cylinders must be machined and new rings installed to bring oil consumption down.

Another cause of excessive oil consumption is a cracked vacuum-pump diaphragm which passes oil into the intake manifold and from there into the engine cylinders where it is burned (see §227).

§216. Automotive lubricants In addition to engine oil, many other lubricants are required for the automobile. Wherever one part slides on or rotates in another part, you will find some kind of lubricant at work protecting the parts from undue wear. The steering system, axles, differential, transmission, brakes, generator, ignition distributor, and so forth, all use special types of lubricant.

1. *Gear lubricants.* The gears in transmissions and differentials must be lubricated with special heavy oils that have sufficient body to resist oil-film puncture and thereby prevent actual metal-to-metal contact between the moving gear teeth. On the other hand, the oil must flow readily even at low temperature so that it does not "channel" as the gears begin to rotate. Channeling of the oil takes place if the oil is so thick that the teeth cut out channels in the oil and the oil does not readily flow to fill the channels.

The lubricant used in hypoid-gear differentials (see *Automotive Transmissions and Power Trains*) is subjected to very severe service since hypoid gears have teeth that not only roll over one another, but also slide over each other. This combined rolling and sliding action puts additional pressure on the lubricant. So that the lubricant will stand up under this service, it is especially compounded and contains certain added chemicals that enable it to withstand much greater pressure than oil alone would withstand. Such lubricants are called extreme-pressure, or EP, lubricants. There are actually two classifications of these lubricants, the powerful extreme-pressure lubricants for use on heavy-duty applications and mild extreme-pressure lubricants for use on applications with less severe requirements.

2. *Grease.* Essentially, lubricating grease is oil to which certain thickening agents have been added. The oil furnishes the lubricating action; the thickening agents simply function to hold the oil in place so that it does not run away. The thickening agents are usually called *soap.* This is not the kind of soap we use in washing, but any one of several metallic compounds; the type used depends on the service required of the grease. This is also true of the viscosity grade (or thickness) of the oil that goes into the grease. For some services, a relatively light oil is used. For others, a heavy oil is used.

a. Aluminum grease. Aluminum grease contains as thickening agent aluminum compounds. This grease has good adhesive properties and is widely used for chassis lubrication. While it will not stand extreme temperatures, it is highly resistant to moisture and is therefore valuable for lubricating springs and other chassis parts subjected to road splash.

b. Soda grease. Soda grease contains as thickening agent sodium compounds that give the grease a thick, fibrous appearance, even though the grease contains no actual fiber. This grease is often called *fibrous grease,* or *fiber grease.* While it is less resistant to moisture than some other greases, it is very adhesive and clings tightly to rotating parts. It is therefore valuable for rotating parts such as wheel bearings and universal joints.

c. Calcium grease. Calcium grease uses calcium compounds as thickening agent. This grease is often known as *cup grease* and is used in lubricating parts supplied with grease cups. It has a tendency to separate into liquid oil and solid soap at high temperatures.

d. Mixed greases. Each of the various greases mentioned above has special valuable characteristics. Mixed greases are blends of these different greases. This blending produces greases that can better meet the requirements of certain specific applications. Actually, the automotive mechanic does not have to worry about the composition of the various greases since the automotive manufacturer and the petroleum company have worked together to produce oils and greases exactly suited for the various parts and places requiring lubrication on the automobile. As long as the automotive mechanic follows the automobile manufacturers' recommendations, he is sure of putting the right lubricant in the right place on the car.

§217. Types of lubricating systems Three types of lubricating systems have been used. These are (1) splash, (2) pressure feed, and

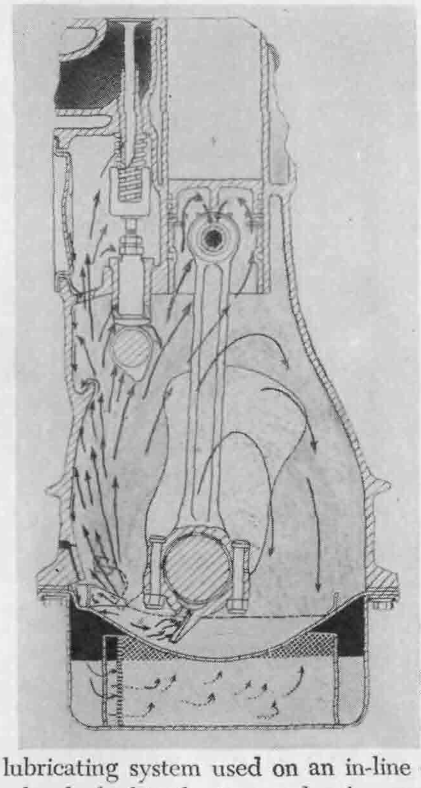


FIG. 11-10. Splash lubricating system used on an in-line engine. An oil pump maintains the proper level of oil in the tray under the connecting rods.

(3) combination splash and pressure feed. The latter two types predominate in modern engines.

1. Splash. In the splash lubricating system, dippers on the connecting-rod bearing caps enter oil trays in the oil pan with each crankshaft revolution (Fig. 11-10). The dippers pick up oil for the connecting-rod bearings and splash oil to the upper parts of the engine. The oil is thrown up as droplets and fine mist and provides adequate lubrication to valve mechanisms, piston pins, cylinder walls, and piston rings. In the engine shown in Fig. 11-10, an oil pump is used to deliver oil to the trays beneath the connecting rods.

2. *Pressure feed.* In the pressure-feed lubricating system (Figs. 11-11 to 11-14), the oil is forced by an oil pump to the various parts

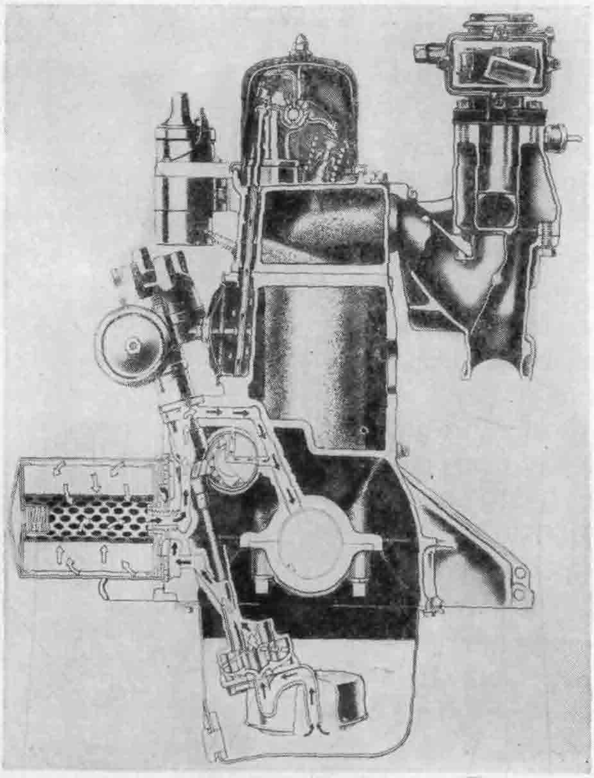


FIG. 11-11. Lubrication system of a six-cylinder overhead-valve engine. Arrows show oil flow to the moving parts in the engine. (*Ford Division of Ford Motor Company*)

of the engine requiring lubrication. The oil from the pump enters an oil line (or a drilled header, or channel, or gallery, as it is variously called), and from the oil line it flows to the main bearings and camshaft bearings. The main bearings have oil-feed holes or grooves that feed oil into drilled passages in the crankshaft. The oil flows through these passages to the connecting-rod bearings. From there, on many engines, it flows through holes drilled in the connecting rod to the piston-pin bearings. Cylinder walls are lubricated by oil thrown off from the connecting-rod and piston-pin bearings. Some engines have oil-spit holes in the connecting rods that index with drilled holes in the crankpin journals with each revolution. As this happens, a stream of oil is thrown onto the cylinder walls (Fig. 11-14). On overhead-valve engines the rocker arms and other valve-mechanism parts are lubricated by an oil line that feeds into the hollow rocker-arm shaft.

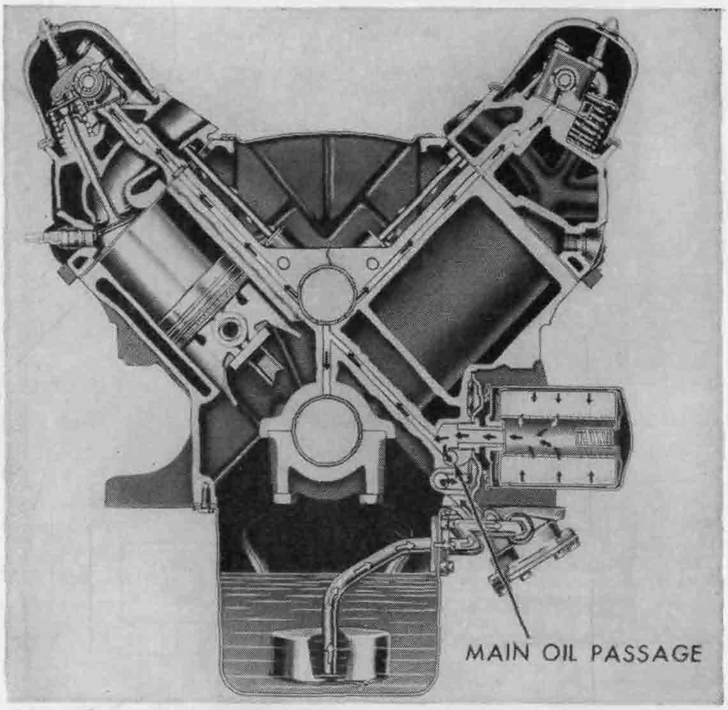


FIG. 11-12. Lubrication system of a V-8 overhead-valve engine. Arrows show oil flow to moving parts in engine. (*Mercury Division of Ford Motor Company*)

3. *Combination splash and pressure-feed system.* The combination splash and pressure-feed lubricating system depends on oil splash to lubricate some engine parts and on pressure feed to lubricate other engine parts. An example of this type of system is shown in Fig. 11-15. In this engine the oil is supplied under pressure to the main bearings, the camshaft bearings, and the valve mechanisms. The connecting-rod bearings are lubricated by means of dippers on the rod bearing caps that dip into troughs in the oil pan. At high

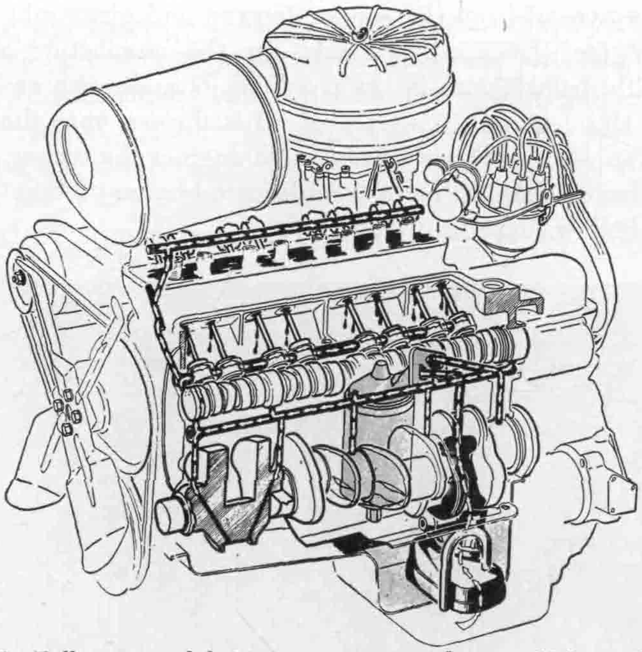


FIG. 11-13. Full-pressure lubrication system used on a V-8 overhead-valve engine. (*Buick Division of General Motors Corporation*)

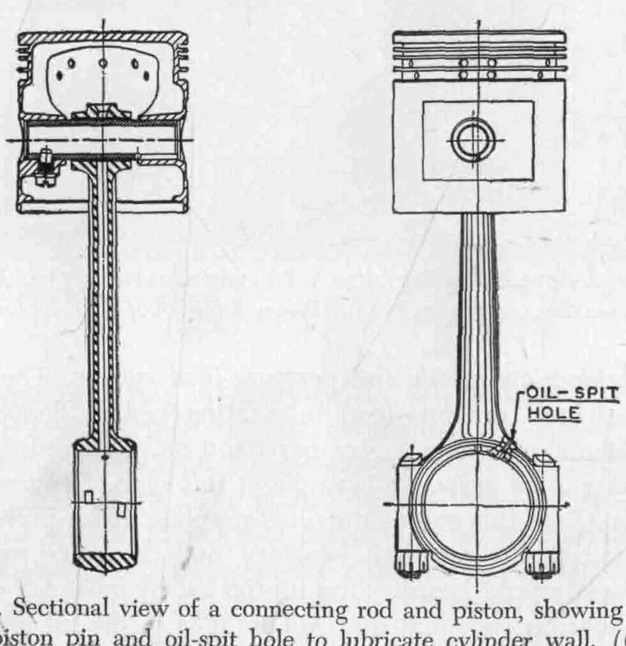


FIG. 11-14. Sectional view of a connecting rod and piston, showing oil hole to lubricate piston pin and oil-spit hole to lubricate cylinder wall. (*Oldsmobile Division of General Motors Corporation*)

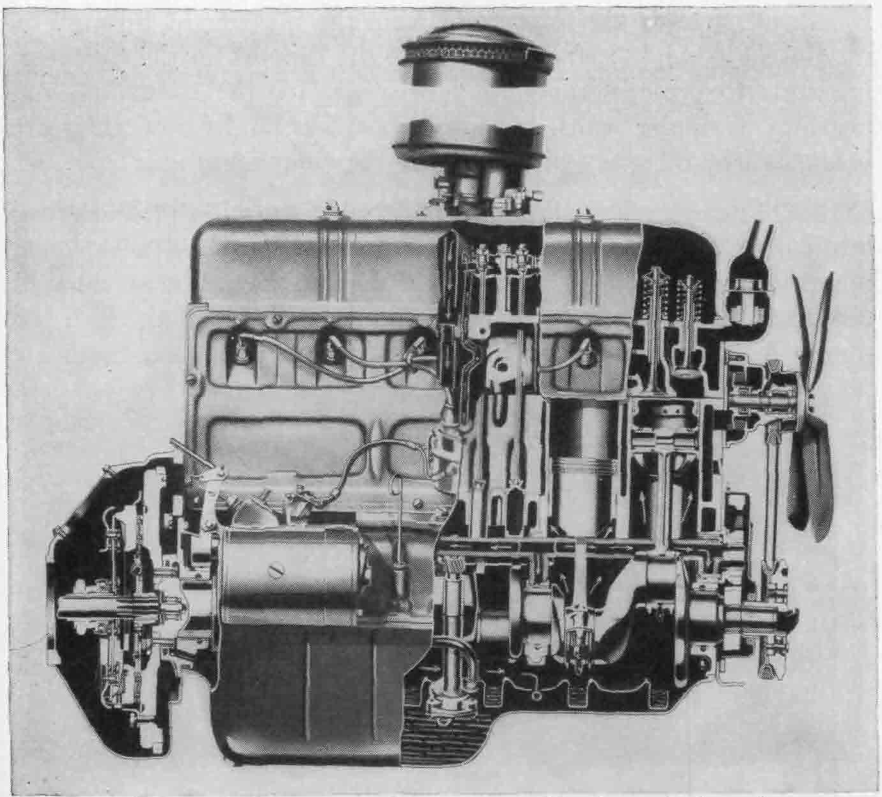


FIG. 11-15. Six-cylinder engine that uses combination splash and pressure-feed lubrication system. (*Chevrolet Motor Division of General Motors Corporation*)

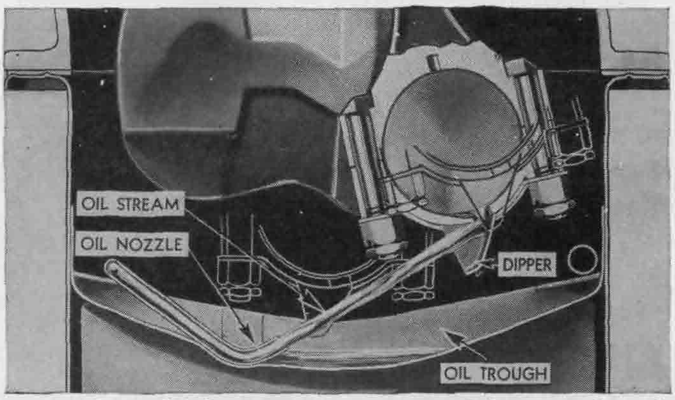


FIG. 11-16. Method of lubricating connecting-rod bearing of engine that is shown in Fig. 11-15. (*Chevrolet Motor Division of General Motors Corporation*)

speed, oil streams are thrown up from the oil troughs through oil nozzles (Fig. 11-16), and these strike the dippers on the rod bearing caps to provide adequate lubrication for the connecting-rod bearings. Cylinder walls, piston-pin bearings, and piston rings are lubricated by oil spray thrown off by the connecting rods.

§218. Oil pumps The oil pumps most widely used in pressure-feed lubricating systems are shown in Figs. 11-17 to 11-21. The gear pump shown in Figs 11-17 and 11-18 depends upon the meshing of a pair of gears to produce the movement of the oil through the pump. As the gears rotate, the spaces between the gear teeth are

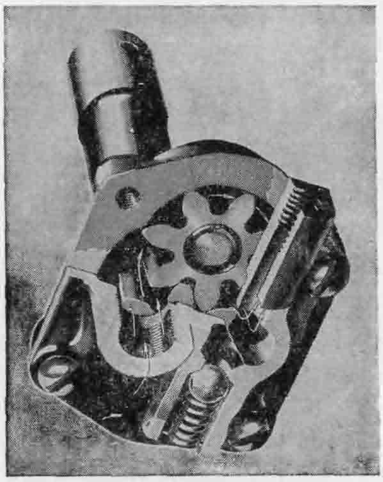
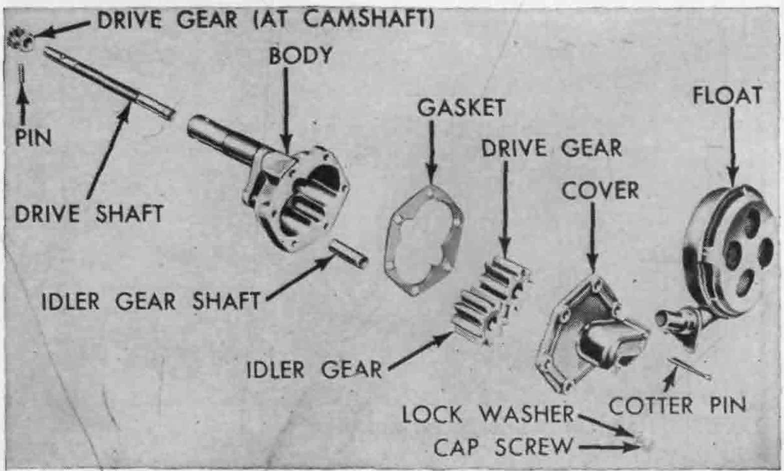


Fig. 11-17. Gear-type oil pump with built-in oil-pressure relief valve. Arrows indicate direction of oil through pump.

Fig. 11-18. Disassembled view of a gear-type oil pump.



filled with oil from the oil inlet. The oil is carried around to the oil outlet, and here the gear teeth mesh to force the oil out from between the teeth. The oil that is forced out is thereby forced to flow through the oil outlet and from there to the various parts of the engine.

The rotor-type pump uses an inner and an outer rotor instead of two gears (Figs. 11-19 to 11-21). This pump is also called an *IO* pump (for inner-outer rotor) or a *dual-rotor* pump. In the assembled pump the inner rotor fits inside the outer rotor as shown in Fig. 11-21. The inner rotor rotates, causing the outer rotor to rotate

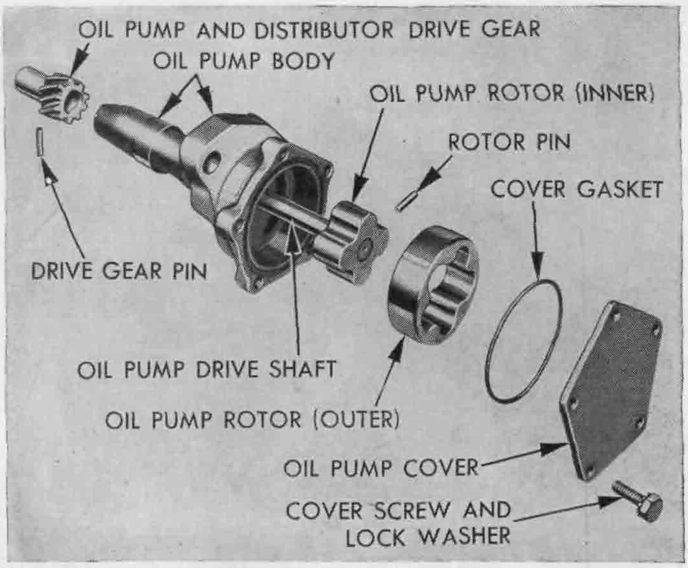
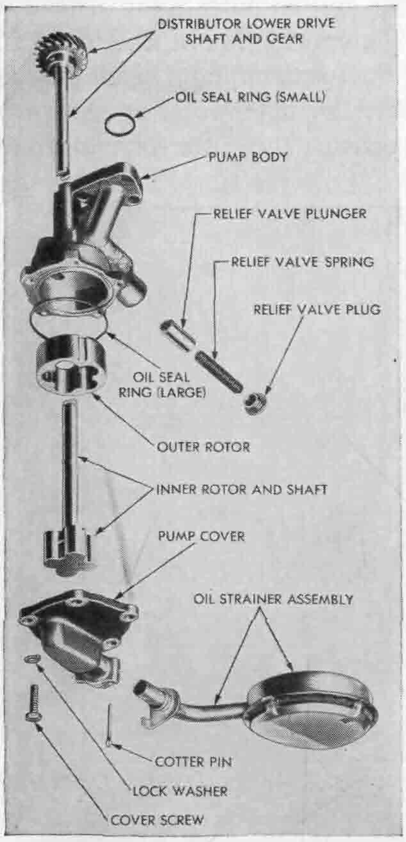


FIG. 11-19. Disassembled view of a rotor-type oil pump. (*Dodge Division of Chrysler Corporation*)

with it. When this happens, oil enters the spaces between the rotors on the side of the pump where these spaces increase in size. Then, as these spaces move further around, the inner rotor lobes move into the spaces and squeeze the oil out. The oil is forced out of the pump through the oil outlet. Note that this pump works almost exactly like the gear pump, the essential difference being that in one, oil is squeezed from between gear teeth, and in the other, oil is squeezed from between the outer rotor and inner rotor lobes.

Oil pumps are usually driven from the engine camshaft, from the same spiral gear on the camshaft that also drives the ignition distributor. On some engines, the driven gear is assembled on the distributor shaft. On others, the driven gear is assembled to the oil-pump shaft. On both types, the two shafts are coupled by a tongue



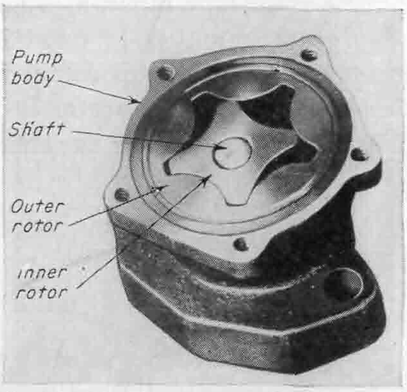


FIG. 11-21. Rotor-type oil pump with cover removed so fit of inner and outer rotors to each other can be seen. (*Plymouth Division of Chrysler Corporation*)

FIG. 11-20. Disassembled view of a rotor-type oil pump which has a built-in pressure relief valve. (*De Soto Division of Chrysler Corporation*)

on one and a groove in the end of the other. Figures 11-12, 11-15, and 11-22 show the location of the oil pump in different engines.

§219. Relief valve In any pressure-feed lubrication system, a relief valve must be incorporated to prevent the building up of excessively high oil pressures during high-speed or cold-weather operation. The relief valve may be incorporated in the oil pump as shown in Fig. 11-17. On this unit the spring-loaded ball is forced off its seat when excessive pressures are approached, permitting oil to flow back into the oil pan through a bypass instead of being forced through the pressure-feed system. The relief valve may be located in other places in the oil line. One type, shown in Figs. 11-23 and 11-24, has the valve located in the cylinder block where it

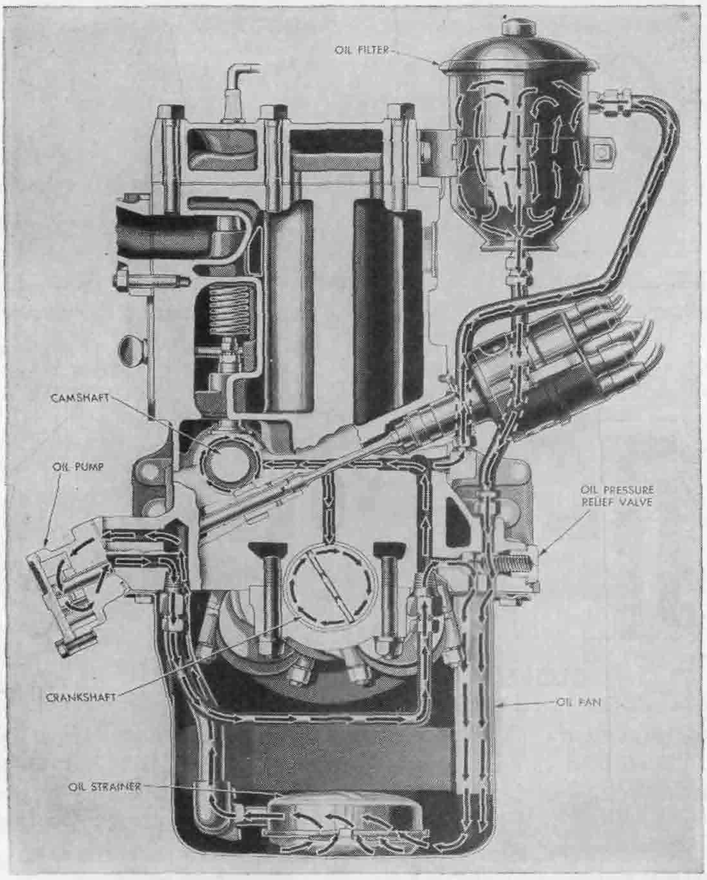


FIG. 11-22. End sectional view of an L-head engine showing location of oil pump, oil filter, and oil-pressure relief valve. Direction of oil flow is shown by arrows. (*Dodge Division of Chrysler Corporation*)

is readily accessible. In operation the pressure-relief valve bypasses a considerable part of the oil from the oil pump, allowing it to return to the oil pan. The oil pump can normally deliver much more oil than the lubrication system requires. This is a safety factor that assures delivery of adequate oil under extreme operating conditions.

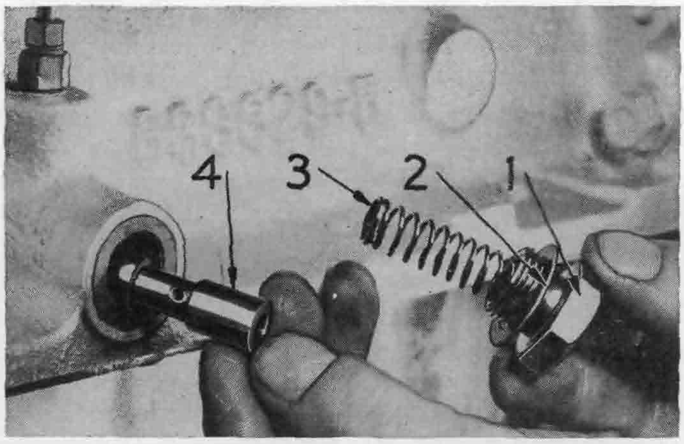


FIG. 11-23. Location of oil-pressure relief valve in cylinder block. 1, cap; 2, gasket; 3, spring; 4, plunger. (*Plymouth Division of Chrysler Corporation*)

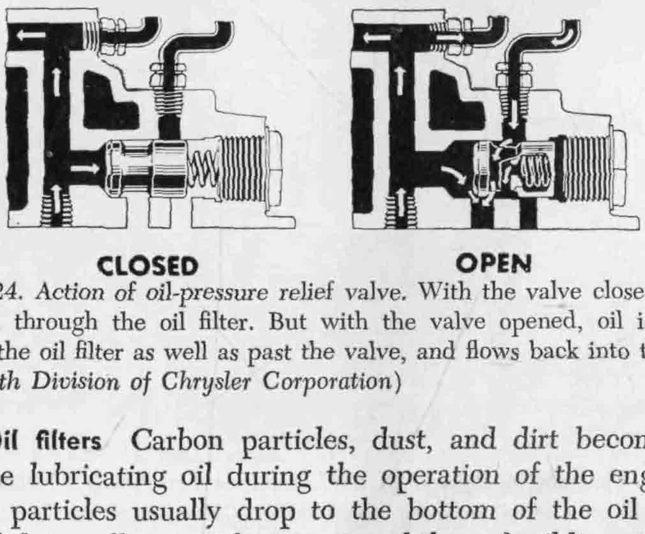


FIG. 11-24. *Action of oil-pressure relief valve.* With the valve closed, no oil is bypassed through the oil filter. But with the valve opened, oil is bypassed through the oil filter as well as past the valve, and flows back into the oil pan. (*Plymouth Division of Chrysler Corporation*)

§220. Oil filters Carbon particles, dust, and dirt become mixed with the lubricating oil during the operation of the engine. The heavier particles usually drop to the bottom of the oil pan, but some of the smaller particles may travel through oil lines to bearing surfaces, where they embed, causing damage to bearings and journals. To reduce damage from this cause, many lubrication systems utilize an oil filter that circulates all or some of the oil from the pump through tightly packed masses of filtering material. The filtering material traps particles of foreign material but permits the oil to pass through. Filters are two types: those that filter part of the oil from the oil pump, called *bypass* filters, and those that filter all the oil in circulation through the system, called *full-flow* filters.

1. Bypass filters. The bypass oil filter (Figs. 11-25 and 11-26) is in most common use. The supply line from the oil pump is so connected as to permit only part of the oil passing through to flow to the oil filter. The remainder of the oil bypasses the oil filter and

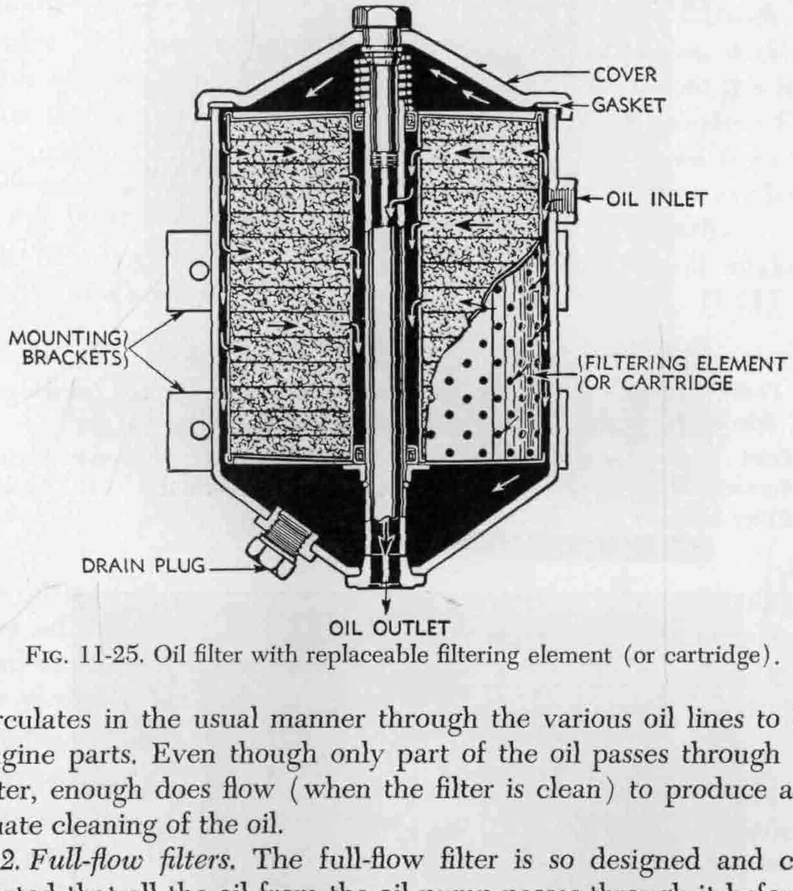


FIG. 11-25. Oil filter with replaceable filtering element (or cartridge).

circulates in the usual manner through the various oil lines to the engine parts. Even though only part of the oil passes through the filter, enough does flow (when the filter is clean) to produce adequate cleaning of the oil.

2. Full-flow filters. The full-flow filter is so designed and connected that all the oil from the oil pump passes through it before it enters the oil lines to the engine parts. The filter used in the engine shown in Fig. 11-13 is of the full-flow type. This type of filter contains a spring-loaded valve that serves as a protection against oil starvation in case the filter becomes so loaded with contaminants that it will not pass enough oil. When this happens, the spring-

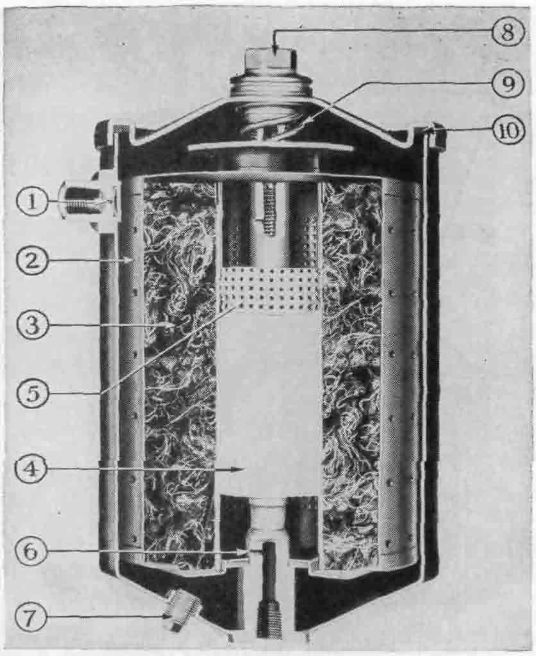


FIG. 11-26. Heavy-duty type of oil filter with replaceable element (cartridge). (*AC Spark Plug Division of General Motors Corporation*)

1. Inlet
2. Screen
3. Filter element
4. Cloth
5. Collector tube
6. Outlet
7. Drain
8. Cover nut
9. Spring
10. Gasket

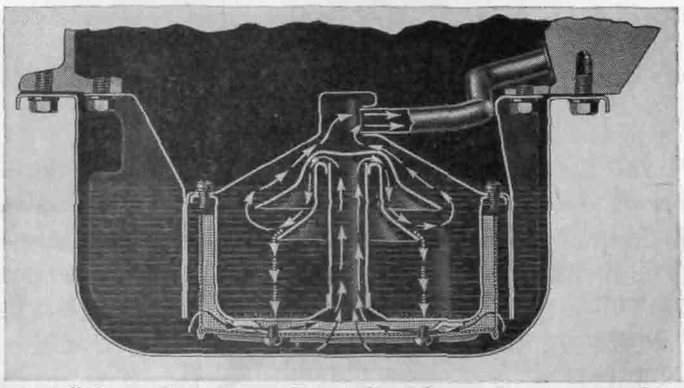


FIG. 11-27. Full-flow oil screen, or filter. All oil from oil pan passes through filter before reaching oil pump and other working parts. (*Pontiac Motor Division of General Motors Corporation*)

loaded valve is opened (by the oil pressure from the pump) and it bypasses the filter so that enough oil can flow to assure adequate lubrication of engine parts. A different sort of full-flow filter, or oil screen, is shown in Fig. 11-27. This is simply a series of screens through which the oil must pass on its way to the oil pump.

3. *Filter-element replacement.* As a filter becomes clogged with foreign particles and impurities, its efficiency decreases. In the bypass filter less and less oil passes through the filter, until finally the filter is practically inoperative and all oil is flowing through the bypass. The same thing takes place in the full-flow filter, with the valve opening to permit the oil to bypass the filter. Before this happens, the filter must be replaced. In some types the complete filter is replaced. In others the filter element only is removed from the filter case and replaced. In the filter-screen arrangement as shown in Fig. 11-27, it is desirable to clean the screens periodically.

4. *Floating oil intake.* In many engines a floating oil intake is used through which oil is pulled to the oil pump (Fig. 11-28). As

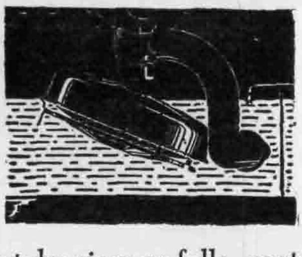


FIG. 11-28. Floating oil intake.

the oil level changes, the floating intake rises or falls, continuing to take oil from the top. Foreign particles that have entered the oil tend to drop to the bottom of the oil pan and are not picked up by the floating intake. Floating oil intakes are shown on several engines in Figs. 11-11, 11-12, and 11-22.

§221. Oil coolers Oil coolers are sometimes used to provide additional cooling of the oil to that which is obtained by means of ribs and fins in the engine oil pan. One type consists of a small radiator mounted on the side of the engine block, through which oil and water circulate. The water passes through the tubes, and the oil flows around the tubes. The water thus absorbs heat from the oil and carries it to the engine radiator, where it is in turn given to the cooling air passing through the radiator. Another design uses a small section of the engine radiator as a cooling device for the oil. The oil is circulated through this section of the radiator, thus giving up its excess heat to the passing air.

§222. Oil-pressure indicators The oil-pressure indicator provides the driver with an indication of the oil pressure in the engine. This gives warning if some stoppage occurs in the lubrication system that prevents delivery of oil to vital parts. Oil-pressure indicators are of two general types, pressure expansion and electric resistance. The latter is the more commonly used.

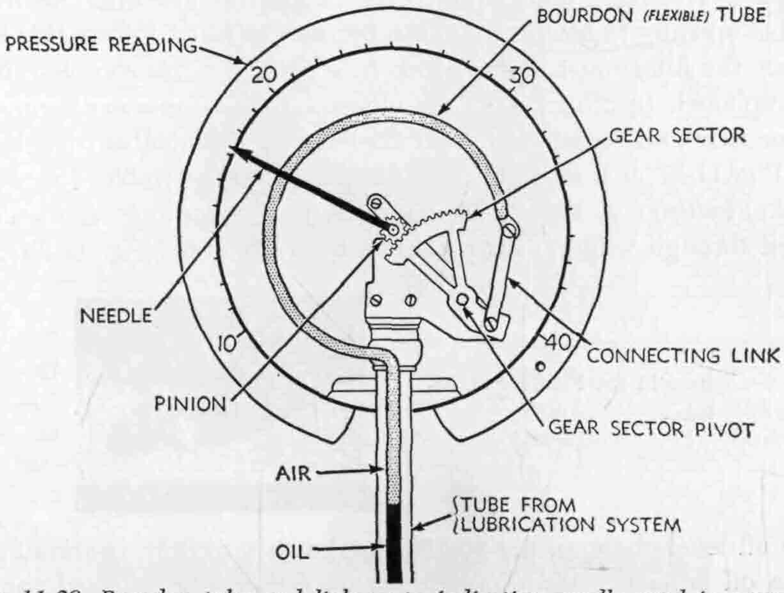


FIG. 11-29. Bourdon tube and linkage to indicating needle used in pressure-expansion oil-pressure indicator.

1. *Pressure expansion.* The pressure-expansion indicator uses a hollow Bourdon (curved) tube that is fastened at one end and free at the other. The oil pressure is applied to the curved tube through an oil line from the engine and causes the tube to straighten out somewhat as pressure increases (Fig. 11-29). This movement is transmitted to a needle by linkage and gears from the end of the tube. The needle moves across the face of a dial and registers the amount of oil pressure.

2. *Electric.* Electrically operated oil-pressure indicators are of two types, the balancing-coil type and the bimetal-thermostat type.

The balancing-coil type makes use of two separate units, the engine unit and the indicating unit (Figs. 11-30 and 11-31). The engine unit (Fig. 11-30) consists of a variable resistance and a movable contact (Fig. 11-31) that moves from one end of the resistance to the other in accordance with varying oil pressure against a diaphragm. As pressure increases, the diaphragm moves inward, causing the contact to move along the resistance so that more resistance is placed in the circuit between the engine and indicating

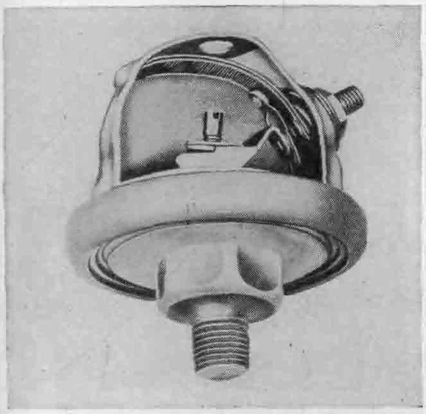


FIG. 11-30. Engine unit of electric-resistance oil-pressure indicator. Housing has been cut away so resistance and movable contact can be seen. (*AC Spark Plug Division of General Motors Corporation*)

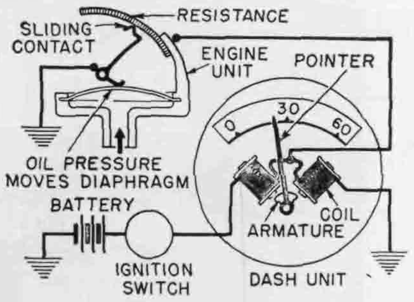


FIG. 11-31. Electric circuit of electric-resistance oil-pressure indicator.

units. This reduces the amount of current that can flow in the circuit. The indicating unit consists of two coils that balance each other in a manner similar to electrically operated fuel gauges (§38). In fact, this type of indicator operates in the same manner as the fuel indicator, the only difference being that the fuel indicator uses a float that moves up or down as the gasoline level changes in the gasoline tank, while in the oil-pressure indicator changing oil pressure operates a diaphragm that causes the resistance change. Refer to the discussion on the operation of the fuel-indicator gauge (§38).

The bimetal-thermostat type of oil-pressure indicator is similar to the bimetal-thermostat fuel gauge (§38). The dash units are practically identical. The engine unit of the oil-pressure indicator, while somewhat different in appearance from the tank unit of the fuel gauge, operates in a similar manner. Varying oil pressure on a diaphragm distorts the engine-unit thermostat blade varying amounts, and this distortion produces a like distortion in the dash-unit thermostat blade, causing the oil pressure to be registered on the dash unit.

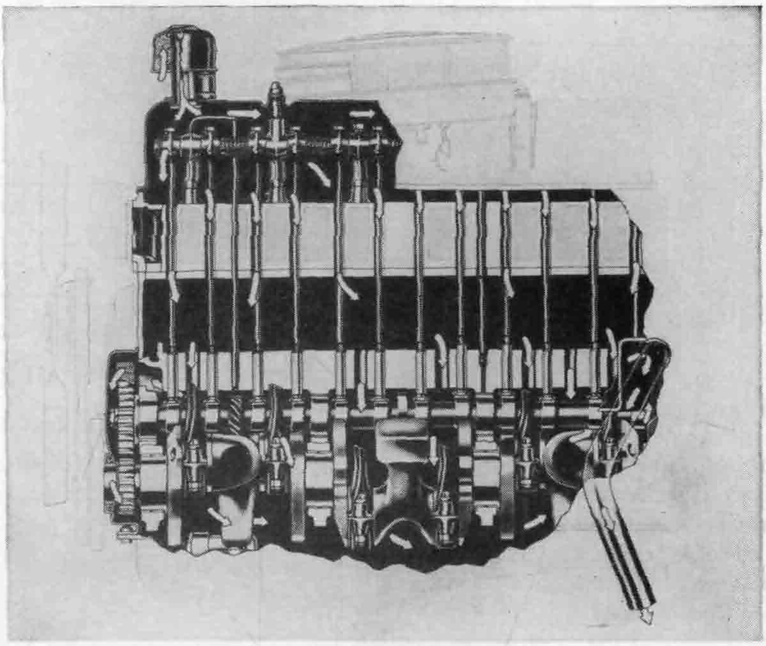


FIG. 11-32. Crankcase ventilating system of a six-cylinder engine. Flow of air is shown by arrows. Air enters through the combination oil filler and breather cap. (*Ford Division of Ford Motor Company*)

§223. Crankcase ventilation As has already been pointed out, water constantly appears in the crankcase as a result of normal engine operation. Since the pistons are constantly moving up and down in the cylinders, the total volume of air in the crankcase is constantly changing. This means that air is being drawn in and expelled. If the engine parts are cold, moisture will condense out of the air. This water tends to mix with the lubricating oil in the crankcase and form sludge (§212). The oil is also diluted by liquid gasoline that seeps down past the piston rings and enters the crankcase. After the engine has reached operating temperature, the water and gasoline will vaporize and, if the crankcase is ventilated, will pass harmlessly out into the air. Crankcase ventilation is generally accomplished by utilizing the natural whirling motion of the air in the crankcase, caused by the rotation of the crankshaft (Fig. 11-32). The air that enters is usually screened through some filter material that helps prevent dust from entering the crankcase.

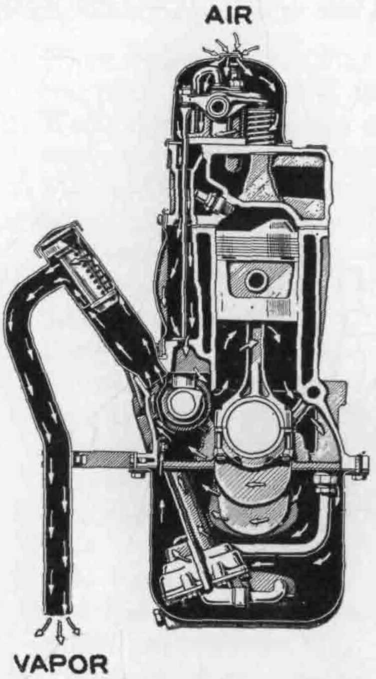


Fig. 11-33. Crankcase ventilating system in an overhead-valve engine.

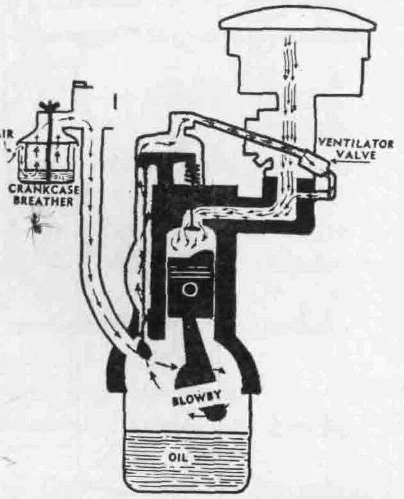


Fig. 11-34. Positive crankcase ventilation.

Figure 11-33 shows, in end sectional view, the crankcase ventilating system of an overhead-valve engine. Figure 11-34 shows a system that assures positive ventilation of the crankcase. In this system, air is drawn directly into the crankcase through an air filter that is similar to (though smaller than) a carburetor air cleaner. After circulating through the crankcase and picking up vapors, the air passes upward to the valve cover. From there, it goes through a tube connected to the intake manifold. Intake-manifold vacuum produces the air movement. The tube to the intake manifold has a valve, or restriction, that prevents excessive amounts of air from bleeding into the intake manifold. If this happened, the air-fuel mixture would be excessively leaned out and poor engine performance would result.

§224. Oil-level indicators In order to determine how much oil remains in the oil pan, oil-level sticks, or "dip sticks," as they are called, are used. The dip stick is so placed at the side of the engine that it protrudes down into the oil (Fig. 11-35). It can be with-

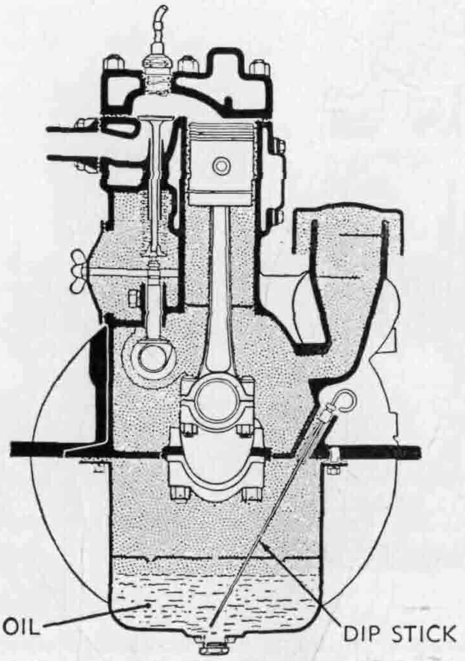


FIG. 11-35. Location of oil-level stick, or dip stick, in engine.

drawn to determine how high the oil is in the pan. When oil is added, it is poured into the oil pan through the oil-filler tube on the side of the engine. The filler tube often serves as the air inlet for the crankcase ventilation system.

CHECK YOUR PROGRESS

Progress Quiz 11

Here is your chance to check up on how well you remember the material you have just finished studying on lubricating systems. The questions that follow help you review the material and fix it more firmly in your mind.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Water sludge forms in the crankcase from the mixing of *water and fuel* *water and oil* *water and air*
2. Water sludge is most apt to form during *cold weather* *warm weather* *changeable weather*
3. The type of car service that is most apt to result in the formation of water sludge is *short-trip operation* *long-trip operation* *trips longer than 14 miles*
4. The three service ratings of lubricating oil for gasoline engines are *SAE 10, 20, and 30* *DS, DG, and DL* *MS, MM, and ML*
5. For so-called "average" car operation the oil should be changed every *500 miles* *1,000 miles* *2,000 miles*
6. Two possible ways that oil might be lost from the engine are by *burning and leakage* *dilution and mixing* *splash and pressure*
7. A grease is essentially a thickening agent to which *aluminum* *soda* *calcium* *oil* has been added.
8. Two types of automotive-engine lubricating systems are *high and low pressure* *pressure and vacuum* *pump and gravity* *splash and pressure*
9. Two types of oil filter are *pass and bypass* *bypass and fullflow* *pressure and gravity*
10. Two types of electric oil-pressure indicators are *balancing-coil and bimetal-thermostat* *pressure-expansion and thermostat* *balancing-coil and pressure-expansion*

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

You are nearing the end of the book and have only lubricating-system service and the cooling system still to cover. You have been making fine progress, and with only a little more effort you will have this volume completed. The material on the engine lubricating system that you have just finished will be of great help to you when you go into the shop. The checkup below will give you a chance to test yourself on how well you remember this material. If you are not sure of an answer, reread the pages that will give you the answer. Reviewing the chapter and writing down the answers will help you remember the important points.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The type of friction commonly present in an automotive engine is *dry friction* *greasy friction* *viscous friction*
2. Other factors being equal, the bearing having the least friction is the *friction bearing* *antifriction bearing* *sleeve bearing*
3. Almost all bearings used in automotive engines are *friction bearings* *antifriction bearings* *guide bearings*
4. In addition to lubricating engine parts to minimize wear and power loss and acting as a cooling agent, the lubricating oil must *improve carburetion, aid fuel pump, and seal* *improve clearances, cool engine, and clean* *absorb shocks, seal, and clean*
5. A measure of how much the viscosity of an oil changes with temperature changes is made by the *viscosity-index scale* *viscosity scale* *detergent-viscosity scale*
6. One way to prevent the formation of water sludge is to *reduce engine temperature* *reduce engine speed* *make longer trips*
7. If you use your car during the winter for short-trip, start-and-stop service, you should use *MS oil* *MM oil* *ML oil* *DS oil*
8. If you use your car during the winter months for short-trip, start-and-stop service, to be on the safe side you should change oil every *500 miles or 60 days* *1,000 miles* *2,000 miles*
9. Two types of oil pump are *vacuum and pressure* *dual rotor and gear* *gear and diaphragm*
10. Two types of oil-pressure indicator are *pressure and vacuum* *pressure expansion and electric* *float and pressure*

Unscrambling the Purposes of Oil

When the two lists below are unscrambled and combined, they will form a list of the jobs that oil does in the engine and the reasons that these jobs must be done. To unscramble the lists, take one item at a time from the list on the left, and then find the item from the list on the right that goes with it. For examples of how this is done, refer to "Unscrambling the Jobs" at the end of Chap. 3. Write the list down in your notebook.

lubricate	to absorb shock loads in bearings
lubricate	to serve as cleaning agent
act as cooling agent	to minimize power loss
resist squeezing out	to form seal between rings and wall
cover rings	to minimize wear
pick up dirt	to remove heat from engine parts

Unscrambling the Properties of Oil

Below, in scrambled form, are two lists giving the properties of oil and the reasons for or definitions of these properties. To unscramble the lists, refer to the directions given in the previous test.

viscosity	viscosity change with temperature
body	to minimize foaming
fluidity	tendency to resist flowing
heat resistant	resistance to oil-film puncture
oxidation resistant	ease with which oil flows
foam resistant	to minimize carbon formation
detergent ability	to minimize oil breakdown
viscosity-index rating	to help keep engine clean

Unscrambling the Service Ratings of Oil

Below, in scrambled form, are two lists giving the service ratings of oil and what they mean. To unscramble the lists, refer to the directions given for "Unscrambling the Properties of Oil," above.

MS	for medium automotive service
MM	for heavy-duty or severe diesel service
ML	for light or normal diesel service
DS	for severe or heavy-duty automotive service
DG	for light automotive service

Definitions

In the following, you are asked to write down certain definitions of important terms, purposes of lubrication-system components, and so on. The act of writing down these answers in your notebook will help you remember them. Also, it makes your notebook a more valuable reference for you to look at when you need to recall important facts about the automobile.

1. List and define the three classes of friction.
2. Define and give examples of friction and antifriction bearings.
3. List six purposes of the engine oil, and explain how the oil accomplishes these purposes.
4. Explain how body and fluidity affect the action of the lubricating oil.
5. Name some properties that a good lubricating oil must have, and explain what these properties are.
6. List the three ways in which oil may be lost from the engine.
7. What are the two main factors affecting oil consumption?
8. Explain why higher engine speeds increase oil consumption.
9. List and describe different lubricating greases used in automobiles.
10. List and describe the three different types of automobile lubrication systems.
11. Name and describe the operation of the two most widely used types of automotive oil pumps.
12. What is the purpose of the relief valve?
13. What is the purpose of the oil filter?
14. Name and describe the operation of the two types of electrically operated oil-pressure indicators.
15. Describe the purpose and operation of the crankcase ventilating system.
16. Where are oil-level indicators usually located and how are they used?

SUGGESTIONS FOR FURTHER STUDY

Examine various engines, oil pumps, filters, and other lubrication-system components so you can better understand how the oil is circulated from the crankcase to the various engine parts. Study the illustrations and descriptions of lubrication systems in all the car shop manuals you can get your hands on. Go to your local library and see what you can find on the subject of lubricating oils, greases, and petroleum refining methods. Write down in your notebook any important facts you come across that you want to be sure to remember.

12: Lubricating-system service

THE PURPOSE of this chapter is to discuss in detail the services required by the engine lubricating system. It must be remembered that the lubricating system is actually an integral part of the engine and that the operation of one depends upon the operation of the other. Thus, the lubricating system, in actual practice, cannot be considered as a separate and independent system; it is part of the engine. The servicing procedures that follow should be considered to be an extension of the engine-servicing procedures outlined in another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*).

§225. Testing instruments The lubricating system is an integral part of the engine, and, consequently, any test of the oiling system involves testing the engine.[1] Thus the pressure tester for detecting oil leaks in the pressure-feed type of lubrication system also detects excessively worn bearings, since worn bearings have excessive clearances that allow oil leakage. Various lubricating-system checks and the troubles encountered in the lubricating system and with lubricating oils are discussed in following paragraphs.

The *pressure tester* for testing the pressure-feed type of lubricating system (Fig. 12-1) consists of a pressure tank partly filled with medium oil, with fittings and hose for attaching the tank to a source of compressed air and to the engine lubrication system. The tester is connected to the outlet line of the oil pump or to any point in the system where oil pressure can be applied. Then, with the oil pan removed so that the main and connecting-rod bearings can be seen, air pressure is applied to the tester tank. This forces oil under pressure into the engine oil lines. Any oil leak, as well as tight bearings or oil-passage obstructions, can thus be readily detected. In addition, a worn bearing will be disclosed, since it would permit

[1] See *Automotive Engines*.

the escape of a steady stream of oil around the ends of the bearing. One manufacturer of an oil-leak detector specifies that with SAE 30 oil and 25 pounds of air pressure, 20 to 150 drops of oil per minute escaping from a bearing indicates that the bearing condition is satisfactory. Less than 20 drops of oil per minute indicates a tight bearing or an obstruction in the oil passage. More than 150 drops per minute indicates worn bearings.

NOTE: When an oil-passage hole in the crankshaft indexes with an oil-passage hole in a bearing, considerable oil will be fed to the bearings, and the oil will stream out as though the bearing were

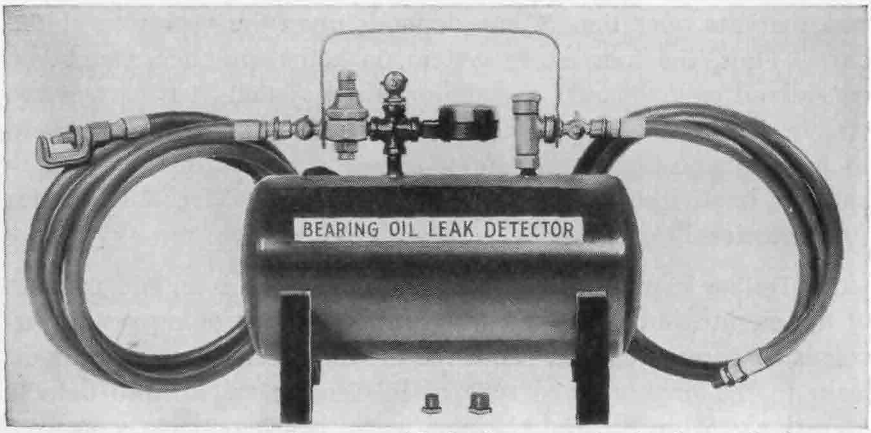


FIG. 12-1. Pressure-type bearing oil-leak detector. (*Federal-Mogul Corporation*)

worn. The crankshaft must be rotated somewhat to move the holes out of index before the test can be made. Bearings that have annular grooves into which oil is constantly fed cannot be tested by this method.

§226. Lubricating-system checks Most engines use a bayonet type of oil-level gauge (the dip stick) that can be withdrawn from the crankcase to determine the oil level in the crankcase (see Fig. 11-35). The gauge should be withdrawn, wiped clean, reinserted, and again withdrawn so that the oil level on the gauge can be seen. The gauge is usually marked to indicate the proper oil level. The appearance of the oil should be noted to see whether it is dirty, thin, or thick. A few drops of oil can be placed between the thumb and fingers and rubbed, to detect dirt or to find out whether the oil has sufficient body, that is, whether it is sticky. If the oil level is low, oil should be added to the crankcase. If the oil is thin or dirty, it should be drained and the crankcase refilled with clean oil.

§227. Trouble tracing in lubricating system Relatively few troubles occur in the lubricating system that are not intimately related to engine troubles. Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) discusses engine troubles.

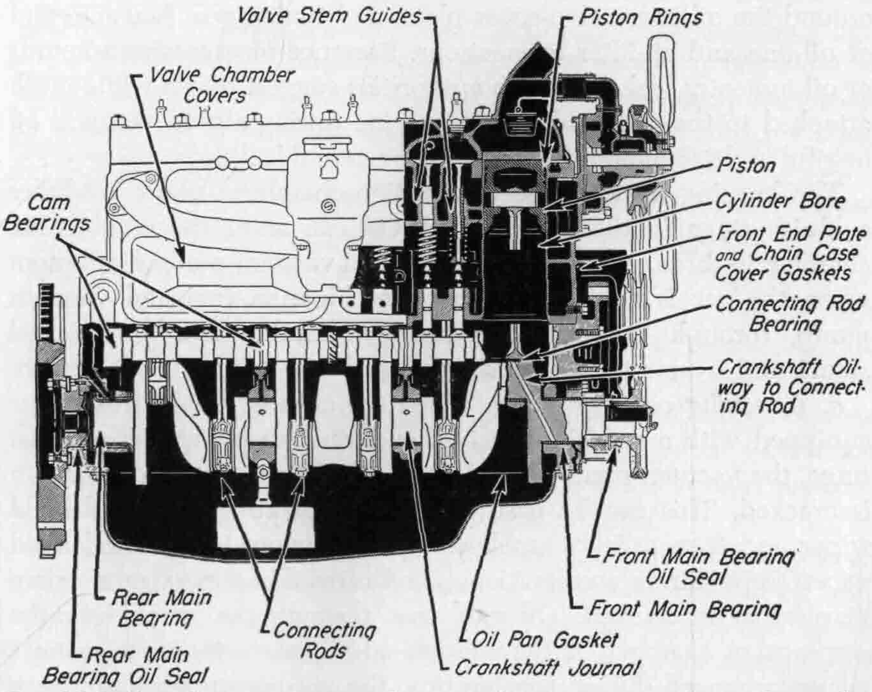


FIG. 12-2. Partial sectional view of engine showing points where oil may be lost. (*Federal-Mogul Corporation*)

The lubricating-system troubles most commonly experienced are discussed below.

1. *Excessive oil consumption.* Most lubricating-system troubles produce excessive oil consumption, the cause of which is not always easy to determine. As was explained in §215, oil is lost from the engine in three ways: by burning in the combustion chamber, by leaking in liquid form, and by passing out of the crankcase through the crankcase ventilating system in the form of vapor or mist. Figure 12-2 shows some of the places at which oil may be lost

from an engine. Excessive oil consumption is not difficult to detect; the need to add oil frequently to maintain the proper oil level in the crankcase makes the condition obvious. The actual amount of oil consumption can be accurately checked by filling the crankcase to the correct level with oil, operating for several hundred miles, and then measuring the additional oil that must be added to bring the oil back to the original level.

External leaks can often be detected by inspecting the seals around the oil pan, valve-cover plate, and timing-gear housing, and at oil-line and oil-filter connections. Presence of excessive amounts of oil indicates leakage. Some authorities suggest that a white cloth attached to the underside of the engine during a road test will be helpful in determining the location of external leaks.

The burning of oil in the combustion chamber usually produces a bluish tinge in the exhaust gas. Oil can enter the combustion chamber in three ways: through a cracked vacuum-pump diaphragm when the car is equipped with a combination fuel and vacuum pump, through the clearance between intake-valve guides and stems, and around the piston rings.

a. Checking vacuum pump. When the exhaust smoke from a car equipped with a combination fuel and vacuum pump has a bluish tinge, the vacuum pump should be checked to see if the diaphragm is cracked. This can be easily done by operating the windshield wiper and then quickly accelerating the engine. If the windshield wiper stops during acceleration, it indicates that the vacuum-pump diaphragm is cracked. Oil can pass through the crack into the combustion chamber. If the windshield wiper continues to operate at normal speed during acceleration, the vacuum-pump diaphragm is not the cause of excessive oil consumption. This test does not, of course, apply to a car without a combination fuel and vacuum pump.

b. Intake-valve guides. A second means by which oil can enter the combustion chamber is through clearance caused by wear between the intake-valve guides and stems. When clearance is excessive, oil will be sucked into the combustion chamber on each intake stroke. The appearance of the underside of an intake valve provides a clue to the condition of its stem and the guide. If the underside of the intake valve has excessive amounts of carbon, the valve guide and possibly the valve stem are excessively worn. Some of the oil that passes around the valve remains on the underside to form carbon. When this condition is found, it is usually necessary to install valve packing or a new valve guide. A new valve also may be required.

c. Rings and cylinder walls. Probably the most common cause of excessive oil consumption is passage of oil to the combustion chamber between the piston rings and the cylinder walls (sometimes known as *oil pumping*). This results from worn, tapered, or out-of-round cylinder walls, or from worn or carboned piston rings. In addition, when the bearings are worn, excessive amounts of oil are thrown on the cylinder walls, so that the piston rings, unable to control all of it, allow too much oil to work up into the combustion chamber.

d. Speed. Another factor that must be considered in any analysis of oil consumption is engine speed. High speed produces high oil temperatures and thin oil. This combination causes more oil to be thrown on the cylinder walls. The piston rings, moving at high speed, cannot function so effectively, and more oil works up into the combustion chamber past the rings. In addition, the churning effect on the oil in the crankcase creates more oil vapor or mist at high speed, and more oil is lost through the crankcase ventilation system. Tests have shown that an engine will use several times as much oil at 60 mph (miles per hour) as at 30 mph.

2. *Low oil pressure.* Low oil pressure can result from a weak relief-valve spring, a worn oil pump, a broken or cracked oil line, obstructions in the oil lines, insufficient or excessively thin oil, or bearings so badly worn that they can pass more oil than the oil pump is capable of delivering. A defective oil-pressure indicator may record low oil pressure.

3. *Excessive oil pressure.* Excessive oil pressure may result from a stuck relief valve, an excessively strong valve spring, a clogged oil line, or excessively heavy oil. A defective oil-pressure indicator may record high oil pressure.

4. *Oil dilution.* When the car is used for short runs with sufficient time between runs to allow the engine to cool, the engine is operating most of the time on warm-up. Under this condition, the oil will be subject to dilution by unburned gasoline seeping down into the crankcase past the piston rings. In addition, water will collect in the crankcase, since the engine does not operate long enough

at temperatures high enough to evaporate the water. These two substances, water and gasoline, will change the lubricating properties of the oil by forming sludge (§212), and engine parts will wear more rapidly. When this type of operation is experienced, the oil should be changed at frequent intervals to remove the water sludge and diluted oil.

§228. Lubricating-system service There are certain lubricating-system service jobs that are done more or less automatically when an engine is repaired. For example, the oil pan is removed and cleaned during such engine-overhaul jobs as replacing bearings or rings. When the crankshaft is removed, it is the usual procedure to clean out the oil passages in the crankshaft. Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) describes the various engine-servicing jobs. Following sections describe such lubricating-system service jobs as changing oil, cleaning the oil pan, servicing the relief valve, changing or cleaning the oil filter, and servicing the oil pump and the oil-pressure indicator.

§229. Changing oil Standard practice is to change the engine oil at 500-, 1,000-, or 2,000-mile intervals, according to the type of operation (§214). Oil filters installed in the system tend to reduce the frequency with which oil will require changing. But they do not eliminate the need for oil changes. Oil should be changed more frequently during cold weather, particularly when short-trip operation predominates. With short-trip operation, the engine operates cold a greater part of the time, and this increases the chances for water sludge to form. More frequent oil changes will remove this sludge before dangerous amounts can accumulate. When the car is operated on very dusty roads, the oil should be changed more frequently. Despite the air filters in the carburetor air cleaner and crankcase ventilator, dust does work its way into the engine, and this is particularly true when the car operates in dusty areas. Changing oil flushes this dust out so that it cannot harm the engine. Car manufacturers recommend that a car that has been driven through a dust storm, for example, should have the oil changed immediately, regardless of how recently the last oil change was made. At the same time, the air filter should be cleaned and the oil filter (if used) changed. In addition to the changing of engine oil, the lubrication of various points in the engine accessories and

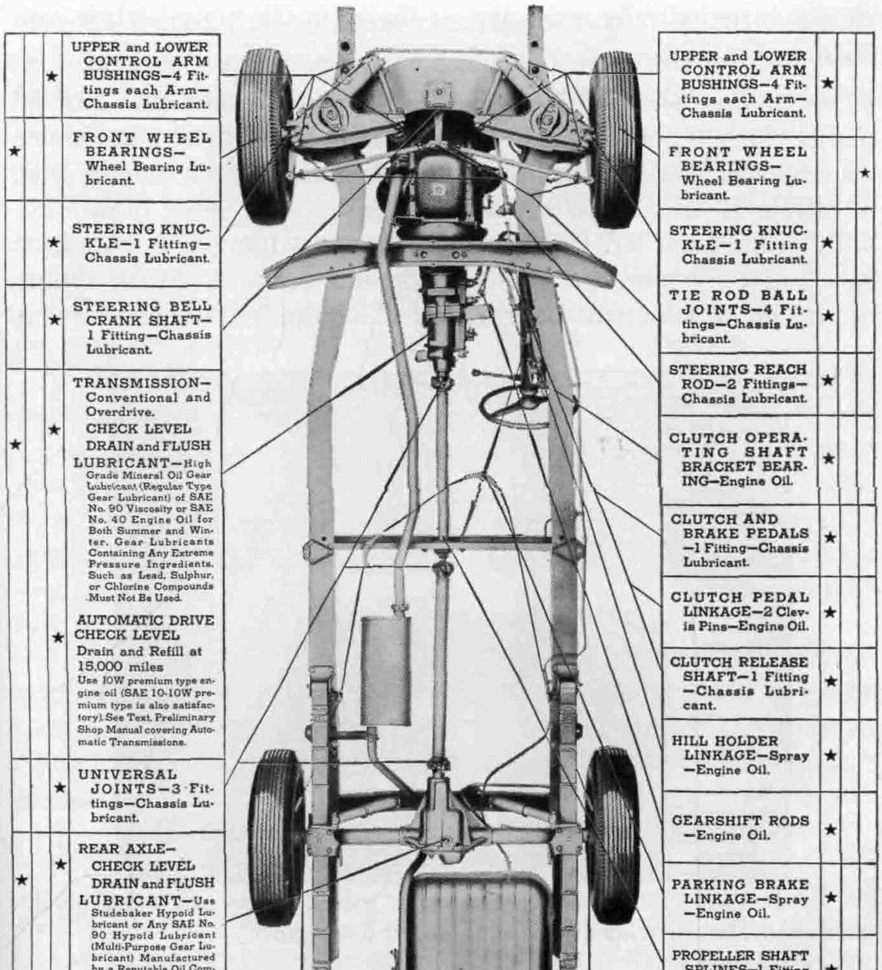


FIG. 12-3. Chassis of one model automobile from bottom, showing items requiring lubrication, type of lubricant to use, and frequency with which service is required. (*Studebaker-Packard Corporation*)

chassis is periodically necessary, as shown in the typical lubrication chart in Fig. 12-3.

§230. Oil-pan service Some authorities recommend that the oil pan be flushed out thoroughly about once a year in order to remove accumulated sludge and dirt. In addition, and for the same reason, oil strainers should be cleaned and engine oil lines blown out with compressed air. On the type of engine using a combination splash and pressure-feed lubricating system (Fig. 11-15) the aiming of the oil nozzles can be checked and adjusted if necessary. A

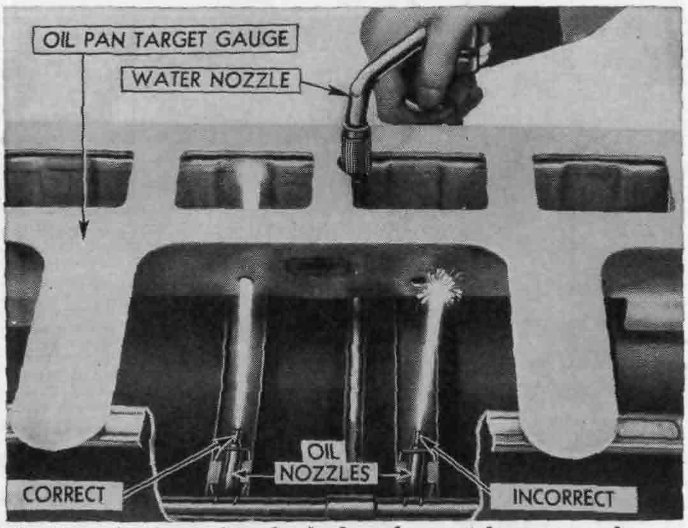


FIG. 12-4. Aim of oil nozzles checked with special gauge and water nozzle. (*Chevrolet Motor Division of General Motors Corporation*)

special oil-pan target gauge is supplied by the engine manufacturer to enable the mechanic to perform this job. Figure 12-4 illustrates the use of such a gauge. Note that the gauge is in position and that water is being applied to the main oil pipe. The oil pan should be tipped at a 45-degree angle to prevent the water from covering the oil nozzles. With the water turned on just enough to straighten the water streams at the end of the nozzles, the water streams should pass through the target holes in the gauge. If they do not, a special oil-nozzle wrench should be used to straighten the nozzles.

1. Removing oil pan. Oil-pan removal varies somewhat on different cars due to interference of various other parts. On many cars, the steering idler or other steering linkage must be detached. In such case, carefully note the manner in which the linkage is attached and also the number of shims (when used), so that the linkage can be correctly reattached. In addition, certain other parts may require removal. For example, on late-model Ford V-8 engines the exhaust crossover pipe, starting motor, and flywheel housing cover must be removed. On earlier models it is necessary to remove engine mounting bolts and to raise the front end of the engine. On Plymouth engines the clutch-housing dust cover should be removed to prevent damage to the oil-pan gaskets.

With the preliminaries out of the way, the drain plug should be removed so that the oil can drain out. Then, attaching bolts or nuts should be taken off so that the oil pan can be removed. To prevent pan from dropping, steady it while the last two bolts are being taken out. If the pan sticks, pry it loose with a screw driver, but proceed carefully to avoid distorting the pan. If the pan strikes the crankshaft and will not come free, turn the engine crankshaft a few degrees so that the counterweights move out of the way.

2. *Cleaning oil pan.* After removal, the oil pan should be cleaned with cleaning solvent or with a steam cleaner. All traces of gasket material and cement should be removed from the pan and engine block. The oil screen should also be cleaned so that all trace of sludge or dirt is removed.

Caution: Before replacing the oil pan, make sure that every trace of solvent has been removed from the pan. Be sure the pan is absolutely clean and dry. Even small amounts of solvent retained in the oil pan may cause engine trouble later. Some types of solvent have a damaging effect on engine parts in a running engine.

3. *Replacing oil pan.* To replace the pan, apply gasket cement to the gasket surfaces of the oil pan. Be sure gasket and pan bolt holes align, and put gasket (or gaskets) into position. Lift oil pan into place and temporarily attach it with two bolts, one on each side. Then examine the gaskets to make sure that they are still in position. Note that on the type of oil pan shown in Fig. 12-5 the end gaskets appear to be somewhat too long so that their ends project slightly beyond the mounting flange of the oil pan. These ends should not be cut off, since they will crush down against the block to provide a better seal. If the gaskets are all still in position,

install the rest of the attaching bolts, and turn them up to the proper tension. Install the oil plug, and add the correct amount and grade of oil. Replace other parts that have been removed or loosened. Check the oil-pan gaskets for leakage after the engine has been run for a while and allowed to warm up.

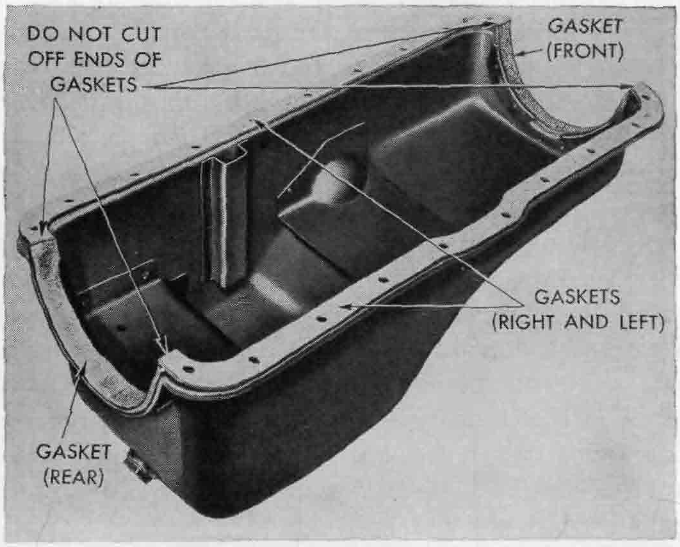


FIG. 12-5. Oil pan with gaskets in place, ready for pan replacement. (*Plymouth Division of Chrysler Corporation*)

§231. Relief valve Most relief valves are not adjustable, but a change in oil pressure can be obtained by installing springs of different tension. This is not usually recommended, however, since a spring of the proper tension is originally installed on the engine, and any change of oil pressure is usually brought about by some defect which requires correction. For example, badly worn bearings may pass so much oil that the oil pump cannot deliver sufficient oil to maintain normal pressure in the lines. Installing a stronger spring in the relief valve will not increase oil pressure, since under such conditions the relief valve is not operating anyway.

§232. Oil filters Oil filters are serviced by replacing the oil-filter element or the complete filter, according to the type. Oil screens are serviced by flushing out accumulated sludge and dirt. Where the application is equipped with a floating type of oil intake, the float and screen should also be cleaned.

As the oil filter becomes clogged, it passes less and less oil. Some indication of the condition of the oil filter can be gotten by feeling it after the engine has been operated for a short time. If the filter is hot to the touch, it indicates that oil is flowing through the filter. If it is cold, the probability is that the filter is clogged and is not passing oil. An additional check can be made by disconnecting the filter outlet with the engine running at low speed to see if oil is flowing through the filter. However, rather than depend on some such check as this to determine filter efficiency, the best procedure is to replace the filter or filter element at periodical intervals. The usual recommendation is to replace the filter element every 5,000 miles. More frequent replacement should be made if the car is operated in unusually dusty conditions.

§233. *Filter-element replacement* To replace the filter element, remove drain plug (if present) from bottom of housing. Take cover off by loosening center bolt or clamp. Lift out element. If filter housing has no drain plug, remove old oil or sediment with a siphon gun. Wipe out inside of housing with clean cloth. Be sure no traces of lint or dirt remain. Install new filter element. Replace plug and cover, using a new gasket. Start engine, and check for leaks around the cover. Note if oil pressure has changed (with a new element, which passes oil more easily, it may be lower). Check level of oil in crankcase, and add oil if necessary. Installing a new filter element usually requires the addition of a quart of oil to bring oil level up to proper height in crankcase.

NOTE: It is always best policy to change the oil whenever the oil filter is changed. The new oil filter should start out with clean oil.

On the type of filter that does not have a replaceable element, the complete filter is replaced. This is done by disconnecting the oil lines to the old filter, dismounting the filter, and then installing the new filter and connecting the oil lines to it.

After a filter element or filter is replaced, the mileage should be marked on the doorjamb sticker and the filter housing. Then, after 5,000 miles (or the specified replacement mileage) the driver and serviceman will know that it is time to replace the filter element again.

§234. Oil pumps The oil pump is a relatively simple mechanism and requires little service in normal operation. If the pump is badly worn, it will not maintain oil pressure and should be removed for repair or replacement. The procedure of removal, repair, and replacement varies on different cars. Typical procedures follow.

1. *Chevrolet.* To remove the oil pump, the oil pan must be drained and removed (§230). Then the oil lines should be disconnected.

a. Disconnect at the block the line going to the block, and disconnect at the pump the line to the screen.

b. Take out the retaining-sleeve lock screw, and remove the oil pump.

c. Detach from the oil pump the line that was connected to the block. Then remove cover-attaching screws, cover, and gears (Fig. 12-6). Remove the oil-pump inlet screen.

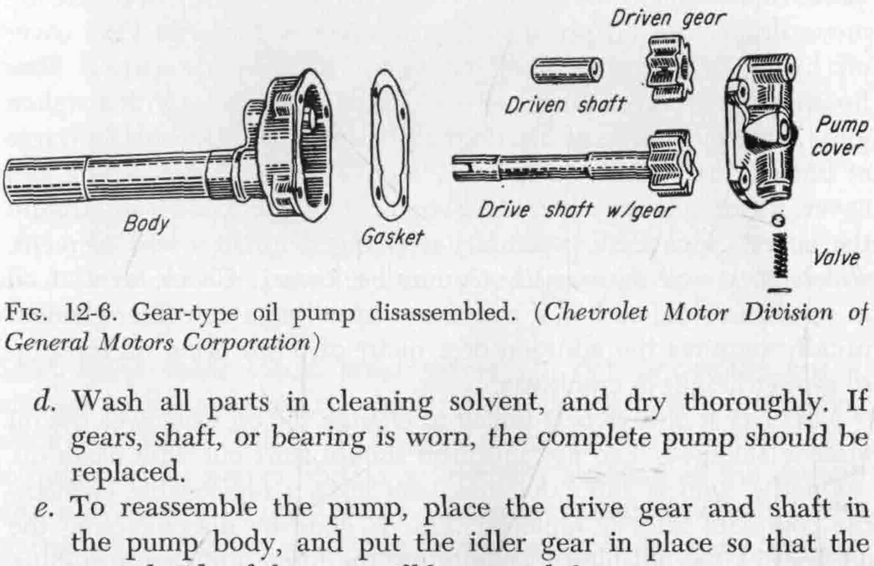


FIG. 12-6. Gear-type oil pump disassembled. (*Chevrolet Motor Division of General Motors Corporation*)

d. Wash all parts in cleaning solvent, and dry thoroughly. If gears, shaft, or bearing is worn, the complete pump should be replaced.

e. To reassemble the pump, place the drive gear and shaft in the pump body, and put the idler gear in place so that the smooth side of the gear will be toward the cover.

f. Put the cover in place with a new gasket, and fasten with screws. After tightening screws, make sure the shaft turns freely.

g. Attach the oil line that goes to engine block, aligning it so it can be readily attached to the block when the pump is replaced. Put pump into place with oil lines aligned. Make sure the drive slot in the shaft aligns with the tang on the distributor shaft.

h. Put retaining-sleeve lock screw in place and tighten it securely, making sure the tapered end of the screw goes into the hole in oil-pump body. Tighten lock nut securely.

i. Connect oil lines. Make sure oil lines fit, to prevent possibility of one oil line drawing pump to one side. This might cause the shaft to misalign and seize.

j. Replace oil pan and add oil (§230).

2. *Plymouth.* Before removing the oil pump, take off the ignition distributor cap and turn the engine crankshaft until the distributor

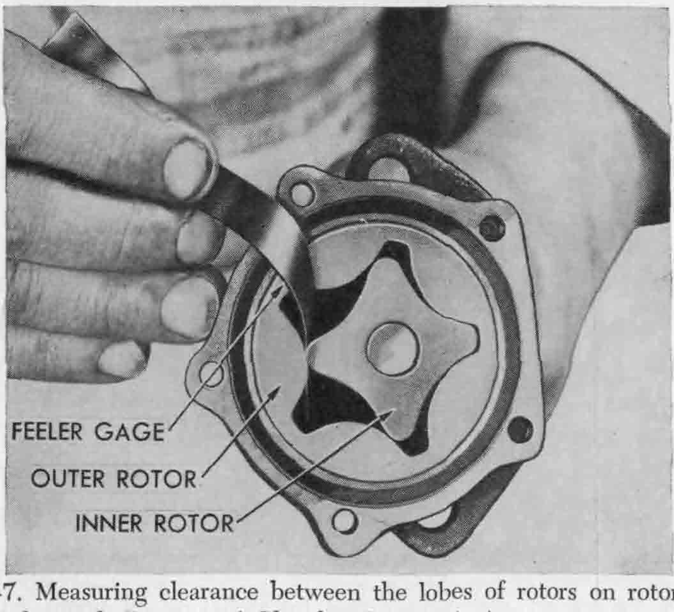


FIG. 12-7. Measuring clearance between the lobes of rotors on rotor-type oil pump. (*Plymouth Division of Chrysler Corporation*)

rotor is in the No. 1 firing position. The oil pump should then be removed. It may be necessary to take off the two upper cap screws from the cover so as to get sufficient clearance for removal of the pump. With the pump off, the crankshaft and distributor shaft should not be moved, since this would change the ignition timing.

a. To disassemble the oil pump, take off the cover, turn it upside down, and rotate the shaft. The outer rotor will slip out; you should catch it in your hand.

b. Then drive out the gear-attaching pin, press the shaft out of the drive gear, and slide the shaft and inner rotor assembly from the pump body. Inspect all parts, and replace any part that appears worn, cracked, or otherwise defective.

c. Clearances between the rotors, body, and cover should be checked. First check the clearance between the high lobes of the rotors as shown in Fig. 12-7. If the clearance is more than 0.010 inch, both rotors should be replaced.

d. Use micrometer to check thickness of both rotors and diameter of the outer rotor. Thickness should not be less than 0.748 inch nor diameter less than 2.245 inches. If less than this, excessive wear has taken place, and rotors should be replaced.

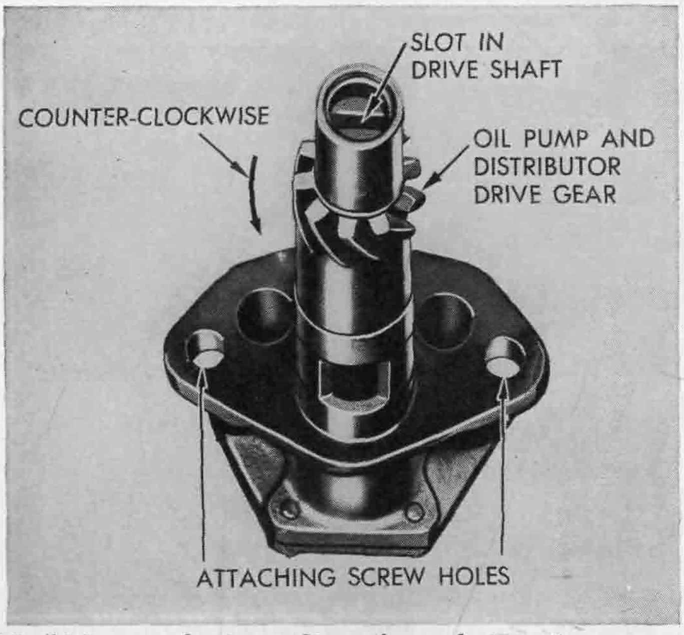


FIG. 12-8. Lining up slot in readiness for replacing oil pump on engine. *(Plymouth Division of Chrysler Corporation)*

e. Replace rotors in pump body, and measure clearance between rotors and a straightedge held across the pump body. This clearance should be 0.004 inch or less. If more, replace the pump body.

f. Push the outer rotor to one side, and check clearance between the outer rotor and pump body. If it is more than 0.008 inch, the pump body should be replaced.

g. If the cover is not absolutely flat or is grooved or scratched, it should be replaced.

h. On reassembly, slide the drive shaft and rotor assembly into the pump body, and then press the drive gear on the shaft until the end play of the shaft is between 0.003 and 0.010 inch. The clearance should be measured between the end of the drive gear and the pump body.

i. Install the gear pin, and peen over the ends. If the pinholes do not line up to provide the proper shaft end play, it will be necessary to drill a new pinhole through the gear and shaft with a $\frac{5}{32}$ drill. This hole should be drilled at right angles to the old hole. With the gear attached, install the outer rotor and cover, using a new gasket.

j. To replace the pump on the engine, first line up the slot in the drive shaft with the two attaching-screw holes in the pump flange. Then turn the drive gear one tooth in a counterclockwise direction as viewed from the shaft end (Fig. 12-8). Next, slide the pump into position without further turning the drive gear. Fasten it with attaching screws.

3. *Ford.* Figure 12-9 is a disassembled view of a late Ford-type oil pump. The oil pump is removed, with the oil pan off (§230), by removing the attaching screws. On some earlier models No. 1 or Nos. 1 and 3 main-bearing caps must also be removed before the oil pump can be taken off.

a. About the only reason for disassembling the oil pump is to replace worn bearings or, possibly, worn gears. Before disassembling the oil pump, check bearing wear by moving the drive shaft from side to side. If the side movement is more than about 0.0005 inch, new bearings should be installed.

b. To disassemble the pump, remove the strainer-assembly retaining screws, strainer, and gasket. Then remove the cover plate and the pump driven gear. Drive out pin, remove the upper driven gear, and slide the shaft and drive-gear assembly from the housing. The pressure relief valve can be removed, if necessary, by cutting the lock wire and taking out the plug, gasket, spring, and valve.

c. On reassembly, coat moving parts with light engine oil, slide the shaft and drive-gear assembly into the housing, and install the upper driven gear with the retaining pin. Rivet the end of the pin over to hold gear in place. When a new shaft and drive-gear assembly is installed, drill a pinhole in the shaft with a No. 30 drill after positioning the gear to give 0.016-inch

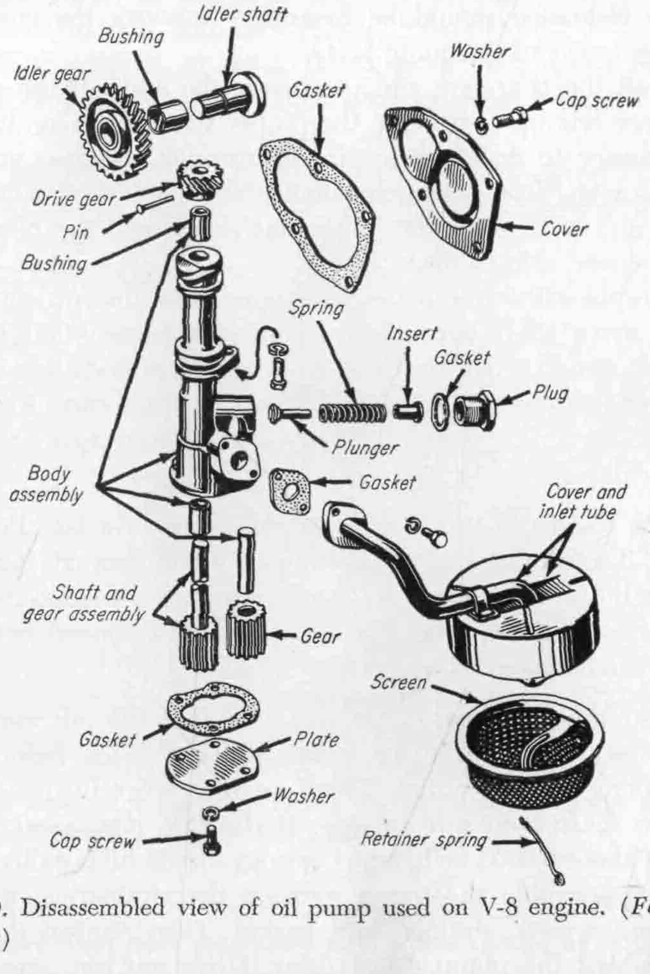


FIG. 12-9. Disassembled view of oil pump used on V-8 engine. (*Ford Motor Company*)

clearance. Then install the pump driven gear, cover-plate gasket, and plate. Install pressure relief valve, spring, gasket, and plug. Lock plug with lock wire, and twist wire around the housing extension. Install strainer gasket and strainer.

d. To install the pump, slide it into the cylinder block, making sure the upper driven gear meshes with the driving gear, and install the pump retaining screw and lock washer. Tighten screw to 12 to 15 lb-ft (pound-feet) torque with a torque wrench. Install oil pan and add oil.

§235. Oil-pressure indicators Oil-pressure indicators are discussed in detail in §222. These units require very little in the way of service. Defects in either the dash unit or the engine unit usually require replacement of the defective unit. On the type of unit that makes use of vibrating thermostatic blades, dirty contact points, which may cause incorrect readings, may usually be cleaned by pulling a strip of bond paper between them. Be sure that no particles of paper are left between the points. Never use emery cloth to clean the points since particles of emery might embed and prevent normal indicator action. If the indicator is not functioning in a normal manner, a new engine indicating unit may be temporarily substituted for the old one in order to determine whether the fault is in the engine unit or the dash unit.

§236. Cleaning valves and piston rings When valves and piston rings have become so clogged with carbon and other accumulations that they cease to operate properly, it may be necessary to overhaul the engine. Use of a detergent type of engine oil (§211, 6) is suggested as one means of reducing the rapidity with which the accumulations form. Also, regular oil changes will tend to remove the impurities held in suspension in the oil before they have a chance to settle on engine parts. Some authorities suggest the introduction of special compounds into the engine oil and through the intake manifold as an aid in freeing sticking valves and rings. Where engine trouble is experienced as a result of carbon accumulations on valves and rings, and where these parts are not excessively worn or damaged, improved engine performance can often be obtained by the use of such compounds without engine overhaul. For information on servicing of valves and piston rings, see *Automotive Engines.*

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

The chapter you have just completed has a number of important facts in it that you will want to remember, since they will help you when you go into the automotive service shop. In order to help you remember these essential facts, the following checkup has been included. You can test your memory and find out whether you are remembering those facts. At the same time, you will be reviewing the chapter and thereby fixing the important points more firmly in your mind. Write down the answers, since this will help you remember.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. Oil is lost from the engine in three ways, by passing as a mist through the crankcase ventilator, by leaking in liquid form, and by *evaporating* *burning in the combustion chambers* *condensing*
2. Oil can enter the combustion chambers in three ways, through a cracked vacuum-pump diaphragm, around the valve stems, and *past the float-bowl needle* *past the manifold gaskets* *past the piston rings*
3. Water sludge forms more rapidly in engine oil with *high-speed driving* *slow-speed driving* *short-trip driving*
4. Oil-filter elements, according to usual recommendations, should be replaced every *1,000* *2,000* *5,000* *10,000* miles
5. Engine oil should be changed, according to usual recommendations for average service, every *100* *1,000* *10,000* miles

Service Procedures

In the following, you should write down in your notebook the information called for. Do not copy the procedures from the book, but try to write them in your own words. Give a step-by-step account of how to do the service jobs asked for. This will help you remember the procedures later when you go into the automotive shop. Try to get hold of various automobile shop manuals, and study them to learn how the various servicing procedures are accomplished. Write up these procedures in your notebook, instead of following the book. This will broaden your general knowledge of the car.

1. Explain how to use the pressure-bearing oil-leak detector.
2. Describe the three ways in which oil is lost from the engine.
3. Describe the three ways in which oil can enter the combustion chambers.

Lubricating-system Service

4. What can produce low oil pressure? Why is this often considered a danger signal?
5. What can produce excessive oil pressure?
6. Under what conditions is it wise to change oil more frequently than usual?
7. Explain how to remove, clean, and replace an oil pan on a specific model car.
8. Explain how to check an oil filter to see if it is operating.
9. Explain how to remove and replace an oil pump on a specific model car.
10. Explain how to disassemble, check, and reassemble an oil pump taken from a specific model car.

SUGGESTIONS FOR FURTHER STUDY

Watch the lubrication men at service stations as they change engine oil and lubricate cars, to learn more about how these jobs are done. Notice that they refer to charts that indicate the points of lubrication on the cars they work on and also show the type and amount of grease or oil to use. Study these charts to get a better idea of these important points. In the automotive shop, notice how oil pans are removed from various cars, and how oil pumps are repaired. Write down in your notebook any important facts you learn, so that you will be sure to remember them.

13: Engine cooling system

THIS CHAPTER discusses the construction and operation of automotive-engine cooling systems. The cooling system is an integral part of the engine, and the operation of one depends on the operation of the other. The cooling system will not operate unless the engine is running; the engine will not operate (for very long) if the cooling system is inoperative. Another book in the McGraw-Hill Automotive Mechanics Series (*Automotive Engines*) discusses engines in detail and describes the relation of the engine and its cooling system.

§237. Purpose of engine cooling system The purpose of the cooling system is to keep the engine at its most efficient operating temperature at all engine speeds and all driving conditions. During the combustion of the air-fuel mixture in the engine cylinders, temperatures as high as 4500°F may be reached by the burning gases. Some of this heat is absorbed by the cylinder walls, cylinder head, and pistons. They, in turn, must be provided with some means of cooling, so that their temperatures will not reach excessive values. Cylinder-wall temperature must not increase beyond about 400 or 500°F. Temperatures higher than this will cause the lubricating-oil film to break down and lose its lubricating properties. But it is desirable to operate the engine at temperatures as close to the limits imposed by oil properties as possible. Removing too much heat through the cylinder walls and head would lower engine thermal efficiency (or heat efficiency—see *Automotive Engines*). Cooling systems are designed to remove 30 to 35 percent of the heat produced in the combustion chambers by the burning of the air-fuel mixture.

Since the engine is quite inefficient when cold, the cooling system includes devices that prevent normal cooling action during engine warm-up. These devices allow the working parts to reach operating temperatures more quickly and shorten the inefficient cold-operating time. Then, when the engine reaches operating temperatures, the cooling system begins to function. Thus, the cooling system cools rapidly when the engine is hot, and it cools slowly or not at all when the engine is warming up or cold.

Two general types of cooling system are used, air cooling and liquid cooling. Automotive engines now employ liquid cooling, although some special engines for airplanes, motorcycles, and so forth, are air-cooled.

§238. Air-cooled engines In air-cooled engines the cylinders are usually semi-independent and not grouped in a block. They are so placed that an adequate volume of air can circulate around each cylinder, absorbing heat in passing. Radial aircraft engines, in

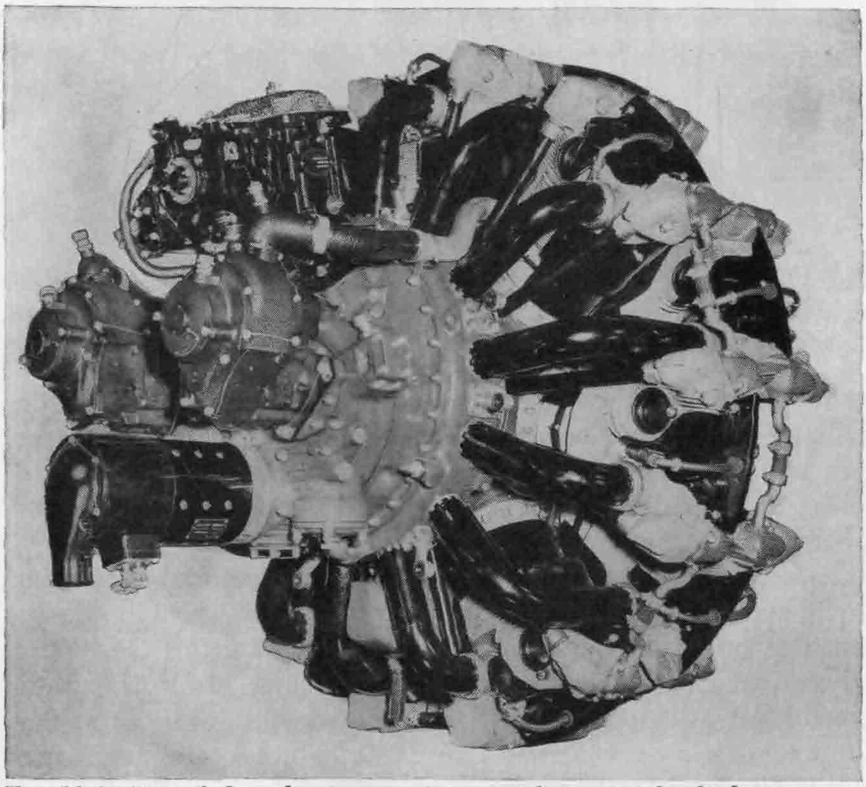


FIG. 13-1. Air-cooled airplane engine. Passage of air around cylinders removes heat from cylinders.

which the cylinders are placed in a circle around a common center, represent this design (Fig. 13-1). Each cylinder normally has a series of ribs or fins, so that the cooling area is considerably increased.

§239. Liquid-cooled engines In liquid-cooled engines, a liquid is circulated around the cylinders to absorb heat from the cylinder walls. The liquid is usually water, to which antifreeze solution is added during cold weather. The heated water is then conducted through a radiator in which the heat in the water is passed on to air that is flowing through the radiator. The water passages, size

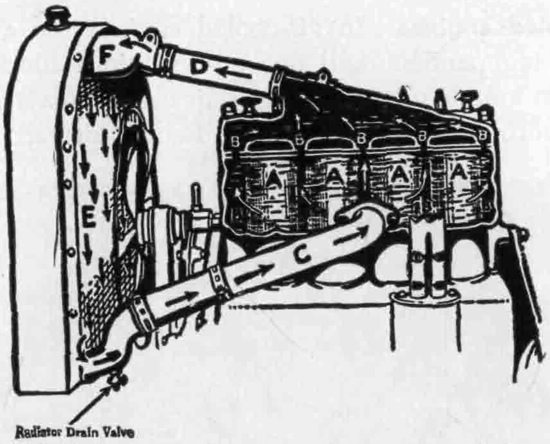


FIG. 13-2. Simplified diagram of water cooling system of thermosiphon type. *A*, cylinders; *B*, waterjackets; *C*, return hose; *D*, upper hose; *E*, radiator; *F*, upper tank.

of radiator, and other details are so designed as to maintain the cylinder walls, head, pistons, and other working parts at efficient, but not excessive, temperatures. Two types of liquid-cooling systems have been used, natural circulation (thermosiphon) and forced circulation.

1. Thermosiphon cooling. Thermosiphon, or natural-circulation, liquid-cooling systems are no longer widely used. This type of system depends upon the expansion of heated water for the motive power that causes the water to circulate (Fig. 13-2). The water around the cylinders is heated and consequently expands so that the weight of a given volume is decreased. Since it is lighter, it rises and is displaced by the cooler and heavier water from the radiator.

The warm water enters the top of the radiator and begins to lose heat to the radiator. As it cools it contracts and becomes heavier, so that it sinks to the bottom of the radiator, continuing to lose heat as it does so. The pressure that it exerts through the return line to the cylinders causes the warmer water around the cylinders to rise. This provides constant circulation of the liquid between the cylinders and the radiator. The hotter the engine, the more

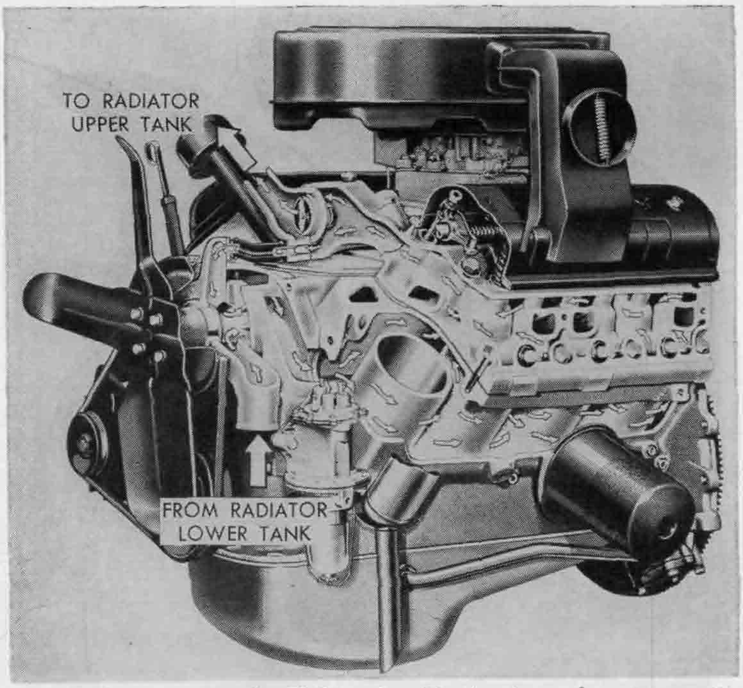


FIG. 13-3. Cooling system of a V-8 engine. Engine is partly cut away to show, by arrows, the circulation of water. The radiator is not shown. See §243 for a discussion of radiators. (*Mercury Division of Ford Motor Company*)

rapidly the water circulates. The system thus tends to maintain fairly constant cylinder-wall temperatures. The disadvantage of the system is that circulation is seriously reduced by any accumulation of scale or foreign matter in the passages and lines, and this in turn causes overheating of the engine.

2. *Forced Circulation.* In the forced-circulation system a water pump (§241) is incorporated (Figs. 13-3 and 13-4) to assure continued and rapid circulation of the cooling liquid.

§240. Water jackets Just as we might put on a sweater or a jacket to keep warm on a cool day, so are water jackets placed around the engine cylinders. There is this difference: water jackets are designed to keep the cylinders cool. Early engines with separately cast cylinders used sheet metal jackets that were attached to the

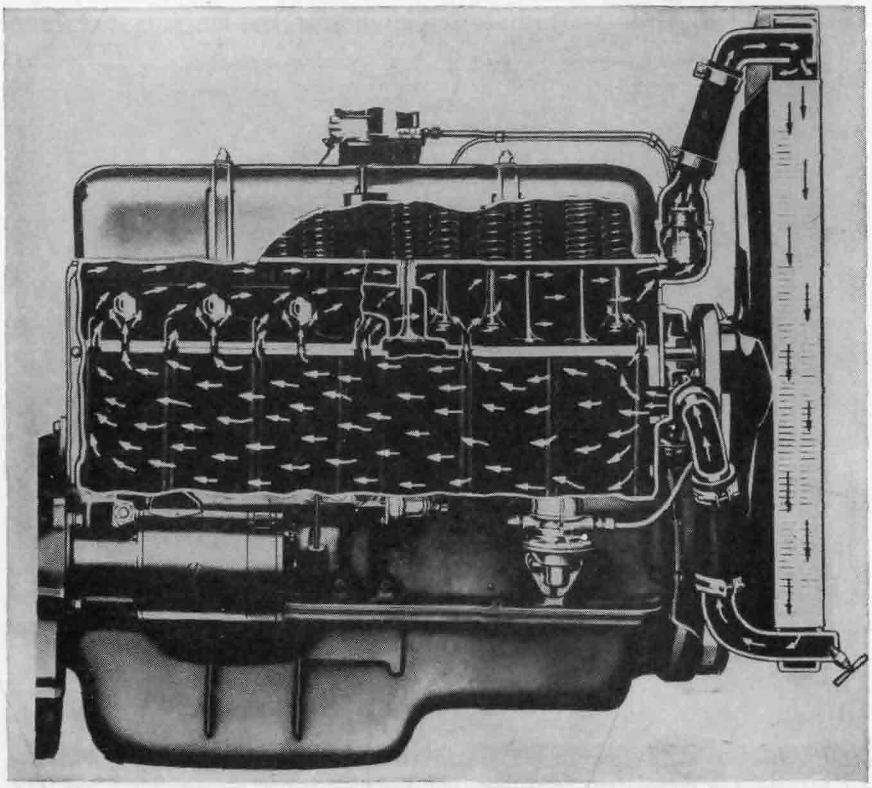


FIG. 13-4. Cooling system used in overhead-valve engine. (*Chevrolet Motor Division of General Motors Corporation*)

cylinders after the cylinders had been completed and assembled to the engine block. This expensive construction was done away with as the casting of intricate cylinder blocks was perfected. In such cylinder blocks the water jackets are cored out (see *Automotive Engines* book) so that water can circulate freely around the cylinders as well as around the valve openings (Figs. 13-3 and 13-4).

On many engines water-distributing tubes are used to direct the

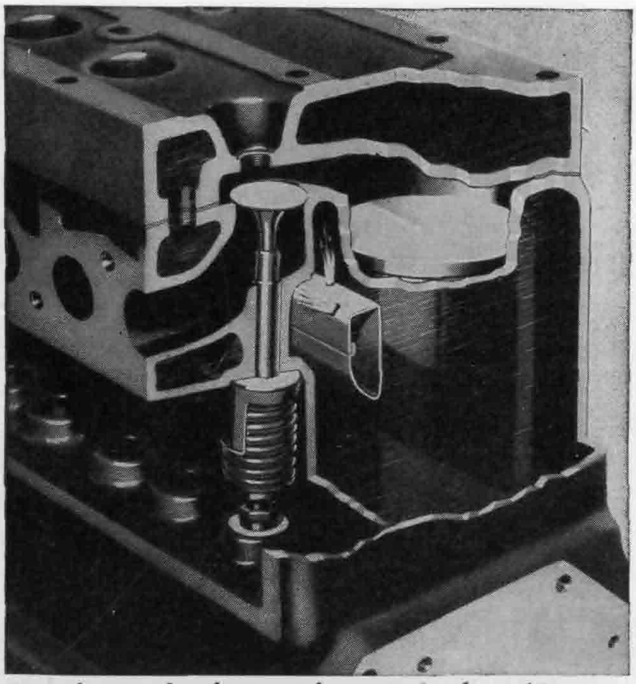


FIG. 13-5. Use of water-distributing tube to cool valves. (*Pontiac Motor Division of General Motors Corporation*)

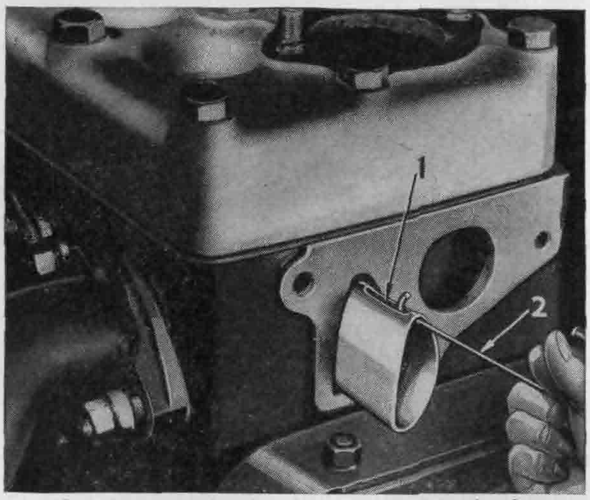


FIG. 13-6. Water-distributing tube (1) being pulled by hook (2) from cylinder block. This tube, similar to the one shown in Fig. 13-5, has holes properly spaced to provide adequate cooling of valve seats. (*Plymouth Division of Chrysler Corporation*)

flow of the cooling water as it enters the water jackets from the radiator. Valve seats and guides must be kept within a safe temperature range, and, by directing a flow of cooling water at them through distributing tubes and nozzles, they are adequately cooled (Figs. 13-5 and 13-6).

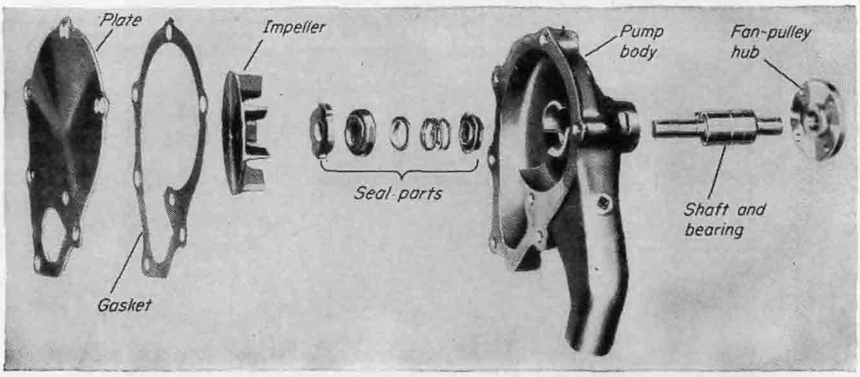


FIG. 13-7. Disassembled view of water pump. (*Pontiac Motor Division of General Motors Corporation*)

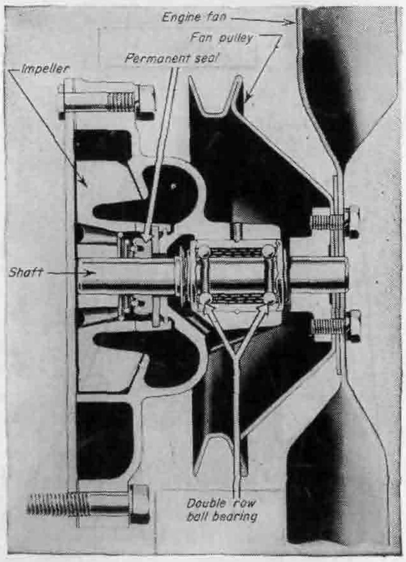


FIG. 13-8. Sectional view of water pump showing manner of supporting shaft on double-row ball bearing and method of mounting fan and pulley on shaft. (*Studebaker-Packard Corporation*)

§241. Water pumps Water pumps are usually of the impeller type and are mounted at the front end of the cylinder block between the block and the radiator (Fig. 13-3). The pump (Figs. 13-7 to 13-10) consists of a housing, with a water inlet and outlet, and an impeller. The impeller is a flat plate mounted on the pump shaft with a series of flat or curved blades, or vanes. When the impeller rotates, the water between the blades is thrown outward by centrifugal force and is forced through the pump outlet and into the cylinder block. The pump inlet is connected by a hose to the bottom of the radiator, and water from the radiator is drawn into the pump to replace the water forced through the outlet.

The impeller shaft is supported on one or more bearings; a seal prevents water from leaking out around the bearing. The pump is

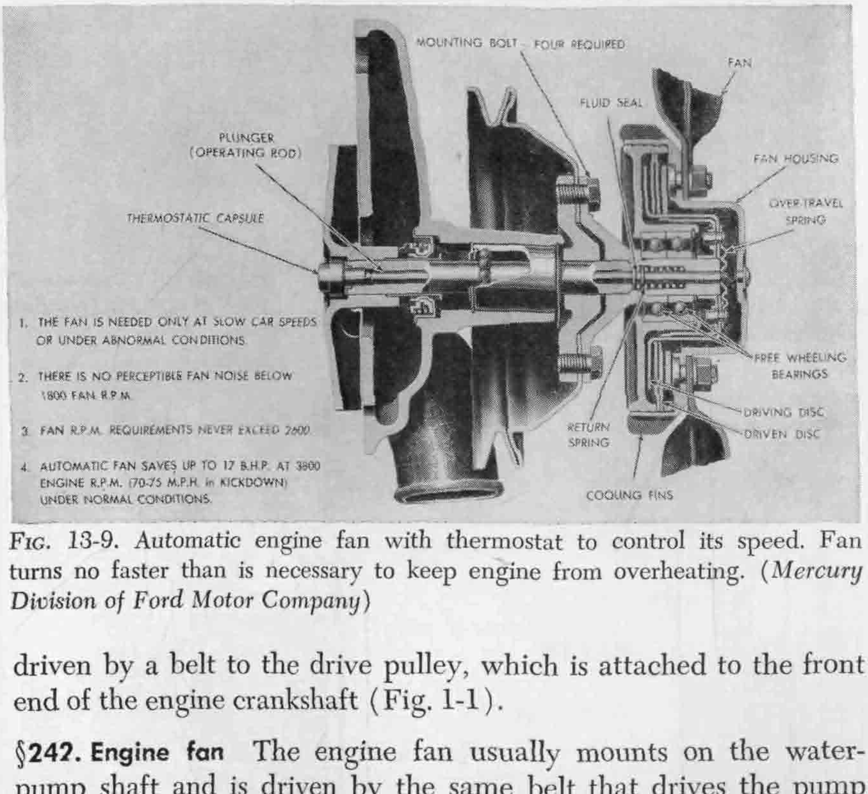


FIG. 13-9. Automatic engine fan with thermostat to control its speed. Fan turns no faster than is necessary to keep engine from overheating. (*Mercury Division of Ford Motor Company*)

driven by a belt to the drive pulley, which is attached to the front end of the engine crankshaft (Fig. 1-1).

§242. Engine fan The engine fan usually mounts on the water-pump shaft and is driven by the same belt that drives the pump and the generator (Fig. 13-8). The purpose of the fan is to provide a powerful draft of air through the radiator to improve engine cooling. The fan usually has from two to six blades, which in rotating pull air through the radiator. Some applications are equipped with a fan shroud that improves fan performance. The shroud increases the efficiency of the fan, since it assures that all air pulled back by the fan must first pass through the radiator.

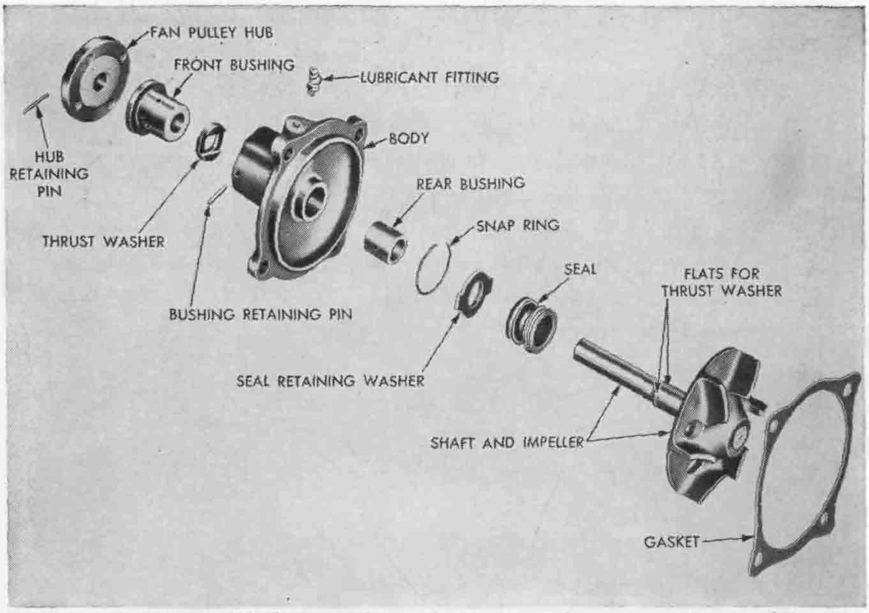


FIG. 13-10. Disassembled view of water pump used in a V-8 engine. (*De Soto Division of Chrysler Corporation*)

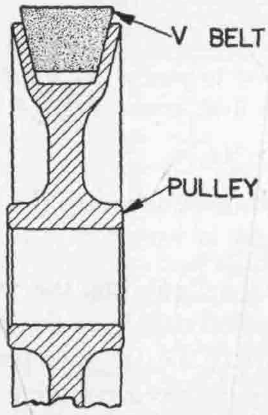


FIG. 13-11. V belt in pulley groove.

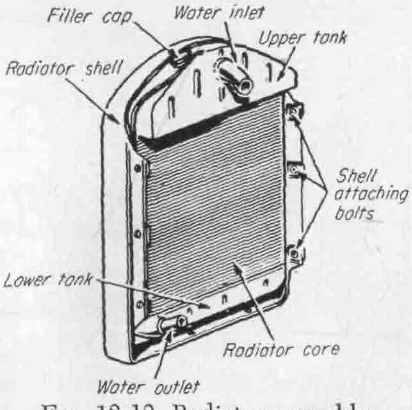


FIG. 13-12. Radiator assembly.

Some engines are equipped with an automatic engine fan that will not exceed a predetermined speed or that will rotate only as fast as is required to keep the engine from overheating. Several types of control are used, including centrifugal and thermostatic. A thermostatically controlled automatic fan is shown in Fig. 13-9. The thermostatic capsule in the fan is subjected to the cooling-water temperature. As the water temperature increases, the thermostat

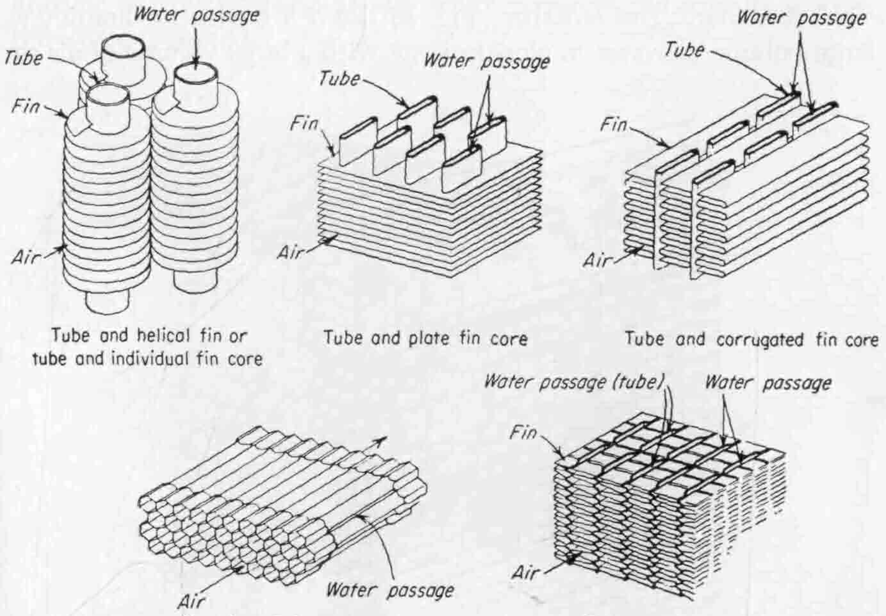


FIG. 13-13. Types of radiator cores.

expands, moving the operating rod toward the fan. This action imposes additional pressure on the clutch disks in the fan hub so that the fan turns faster. When the cooling-water temperature drops, the thermostat contracts, less pressure is exerted on the clutch disks, and the fan turns slower. In the unit shown, the maximum fan speed is about 2,600 rpm. Since the fan will not turn faster than this, even though the fan pulley may be turning much faster, considerable power is saved. In fact, the unit shown is said to save as much as 17 brake horsepower at 3,800 engine rpm. Furthermore, since the fan never turns at very high speed, fan noise is kept to a minimum.

Most fan belts are V type (Fig. 13-11). Friction between the sides of the belt and the sides of the grooves in the pulley causes the driving power to be transmitted through the belt from one pulley to the other. The V-type belt provides a substantial area of contact, so that considerable power may be transmitted; the wedging action of the belt as it curves into the pulley grooves aid in preventing belt slippage. Figure 1-1 shows a V belt in place on the generator, engine fan, and crankshaft pulley of an engine.

§243. Radiator The radiator (Fig. 13-12) is a device for holding a large volume of water in close contact with a large volume of air so

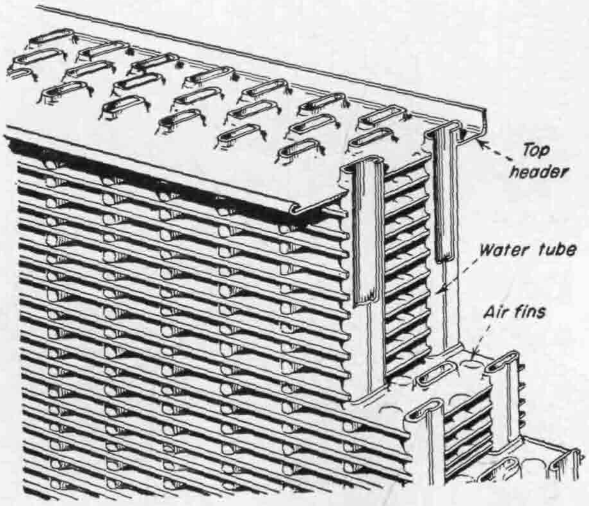


FIG. 13-14. Construction of tube-and-fin radiator core.

that heat will transfer from the water to the air. The radiator core is divided into two separate and intricate compartments; water passes through one and air passes through the other. Radiator core are of five basic types (Fig. 13-13). Two of the more commonly used types for passenger cars are the tube-and-fin (Fig. 13-14) and the ribbon-cellular (Fig. 13-15). The tube-and-fin type consists of a series of tubes extending from the top to the bottom of the radiator (or from upper to lower tank). Fins are placed around the tube to improve heat transfer. Air passes around the outside of the tubes between the fins, absorbing heat from the water in passing.

The ribbon-cellular radiator core (Fig. 13-15) is made up of a large number of narrow water passages formed by pairs of thin metal ribbons soldered together along their edges, running from the upper to the lower tank. The edges of the water passages, which are soldered together, form the front and back surfaces of the radiator core. The water passages are separated by air fins of metal ribbon, which provide air passages between the water passages. Air moves through these passages from front to back, absorbing heat from the fins. The fins, in turn, absorb heat from the water moving downward through the water passages. As a consequence, the water is cooled.

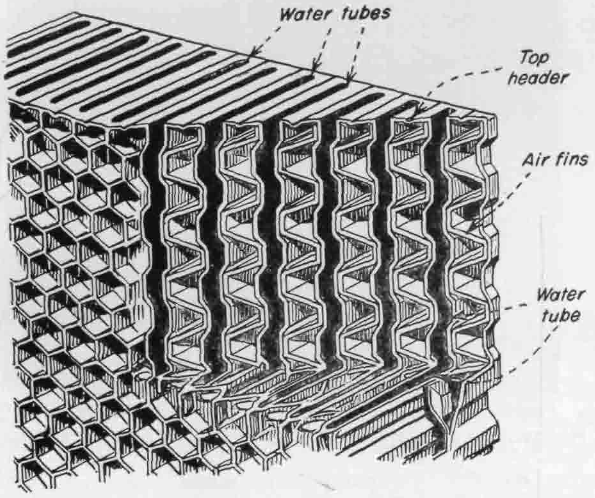


FIG. 13-15. Construction of ribbon-cellular radiator core.

On every radiator a water chamber, or tank, is provided at the top of the radiator, into which hot water is delivered from the engine. A filler cap placed on the water chamber can be removed in order to add water to replace that lost by evaporation or leakage.

Radiator grills, which add to the streamlined appearance of the car, place some added load on cooling systems, since they tend to restrict the flow of air through the radiator. However, where they are used, the cooling system is designed to meet all cooling requirements adequately.

§244. Hot-water car heater Many automobiles are equipped with car heaters of the hot-water type (Fig. 13-16). This device might

Most fan belts are V type (Fig. 13-11). Friction between the sides of the belt and the sides of the grooves in the pulleys causes the driving power to be transmitted through the belt from one pulley to the other. The V-type belt provides a substantial area of contact, so that considerable power may be transmitted; the wedging action of the belt as it curves into the pulley grooves aids in preventing belt slippage. Figure 1-1 shows a V belt in place on the generator, engine fan, and crankshaft pulley of an engine.

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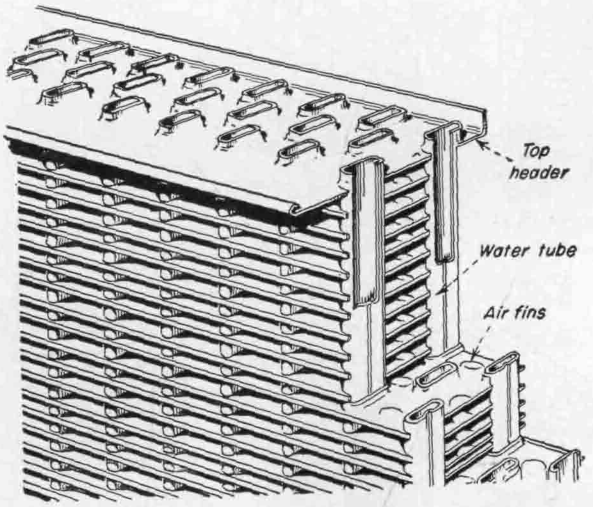

Fig. 13-14. Construction of tube-and-fin radiator core.

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The ribbon-cellular radiator core (Fig. 13-15) is made up of a stamped "170" should start to open at 166 to 174°F and be fully opened at 194°F. Thermostats of the proper characteristics are selected to suit the operating requirements of engines on which they are used.

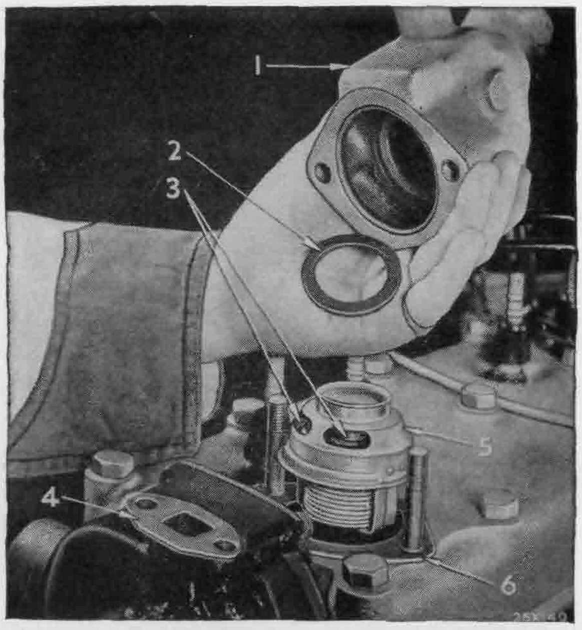


FIG. 13-17. Thermostat, used to restrict water circulation with engine cold, shown in place in cylinder head. (*Plymouth Division of Chrysler Corporation*)

1. Elbow
2. Gasket
3. Thermostat openings
4. Gasket
5. Thermostat
6. Gasket

With the engine cold and the thermostatic valve consequently closed, the water pump circulates the water as shown in Fig. 13-19. The water is merely recirculated through the cylinder block and head. *A small spring-loaded bypass valve is forced open by the* water pressure from the pump so that the water can circulate as shown by the arrows. Restriction of water circulation in this manner prevents the removal of any appreciable amount of heat from the engine by the cooling system, and the engine consequently reaches operating temperatures more rapidly. When the engine reaches operating temperature, the thermostatic valve begins to open, and water can then circulate through the radiator as shown in Fig. 13-20. Figure 13-18 shows the water circulation through the ther-

nostat when the thermostat is open. Operation of the cooling sys-
em then proceeds in a normal manner as already described.

Instead of the spring-loaded-valve type of bypass for water recirculation with the thermostatic valve closed, shown in Fig. 13-19,

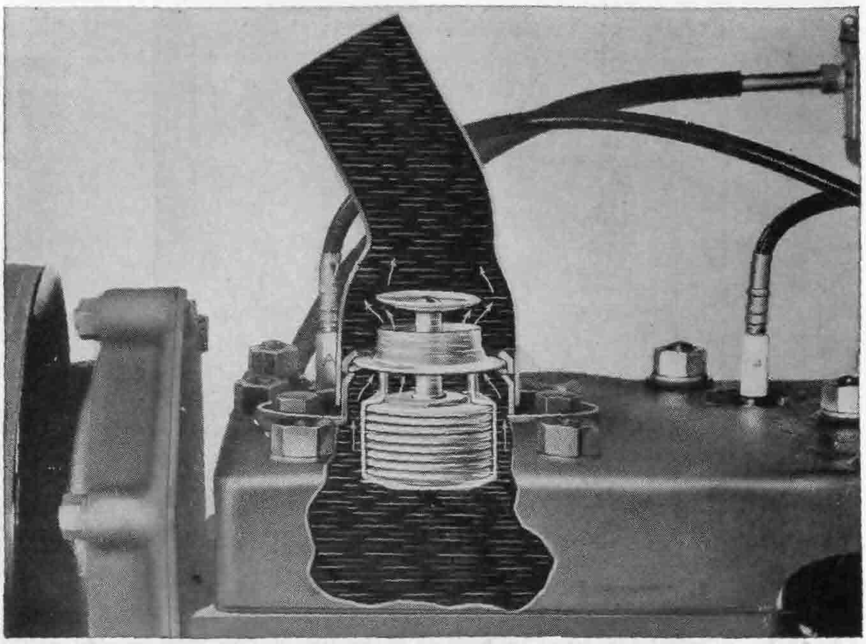


FIG. 13-18. Thermostat in place in cylinder head, showing water circulation through thermostat when thermostat is opened. (*Studebaker-Packard Corporation*)

some engines use a small bypass passage from the cylinder head through the engine block to the pump inlet.

§246. Radiator pressure cap To improve cooling efficiency and prevent evaporation and surge losses, many late automobiles use a pressure cap on the radiator (Figs. 13-21 and 13-22). At sea level, where atmospheric pressure is about 15 psi (pounds per square inch), water boils at 212°F. At higher altitudes, where atmospheric pressure is less (§34), water will boil at lower temperatures. Higher pressures increase the temperature required to boil water. Each added pound per square inch increases the boiling point of water about 3¼°F. The use of a pressure cap on the radiator increases the air pressure within the cooling system several pounds per square inch, so that the water may be circulated at higher temperatures without boiling. The water thus enters the radiator at a higher temperature, and the difference in temperature between the air and the water is greater. Heat then is more quickly transferred from the

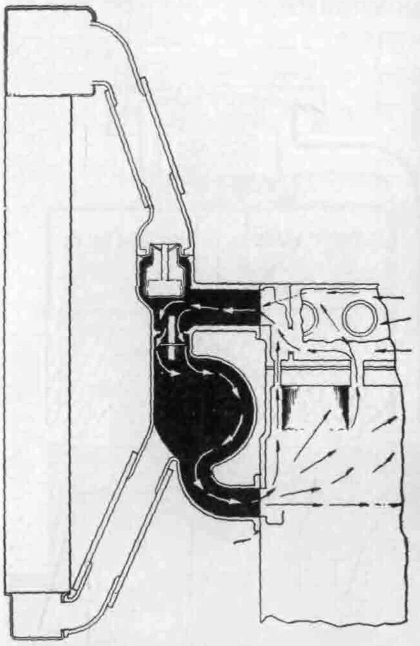


FIG. 13-19. Location of thermostat in water passage between cylinder head and radiator. Engine is cold, thermostat closed, and bypass valve open. Water circulates as shown by arrows. (*Buick Motor Division of General Motors Corporation*)

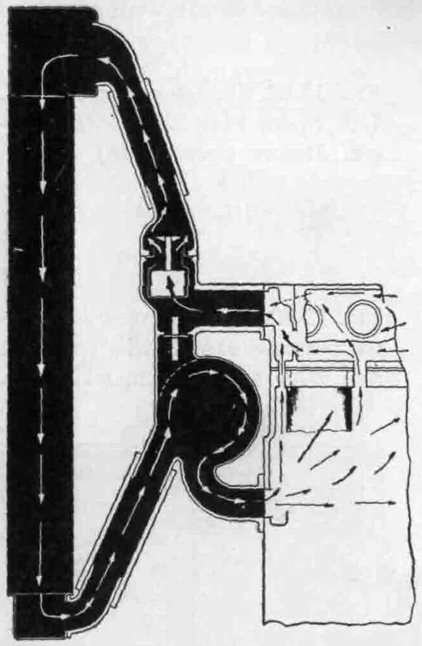


FIG. 13-20. Circulation of water with thermostat open. Some systems incorporate a bypass valve as shown here and in Fig. 13-19. Other systems use a bypass port. (*Buick Motor Division of General Motors Corporation*)

water to the air, improving cooling efficiency. Evaporation of water is reduced by the higher pressure, inasmuch as the boiling point of the water is higher. The pressure cap also prevents loss of water due to surging when the car is quickly braked to a stop.

The pressure cap fits over the radiator filler tube and seals tightly around the edges. The cap contains two valves, the blowoff valve and the vacuum valve. The blowoff valve consists of a valve held against a valve seat by a calibrated spring. The spring holds the valve closed so that pressure is produced in the cooling system. If pressure is obtained above that for which the system is designed, the blowoff valve is raised off its seat, relieving the excessive pressure. Pressure caps are designed to provide as much as 12 pounds of pressure per square inch in the cooling system; this increases the boiling point of the water to as much as 250°F.

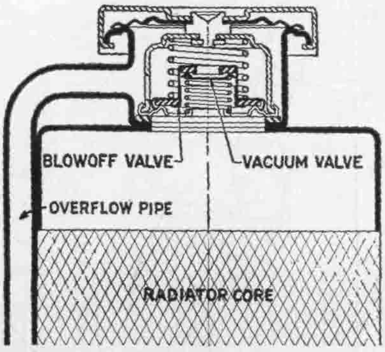
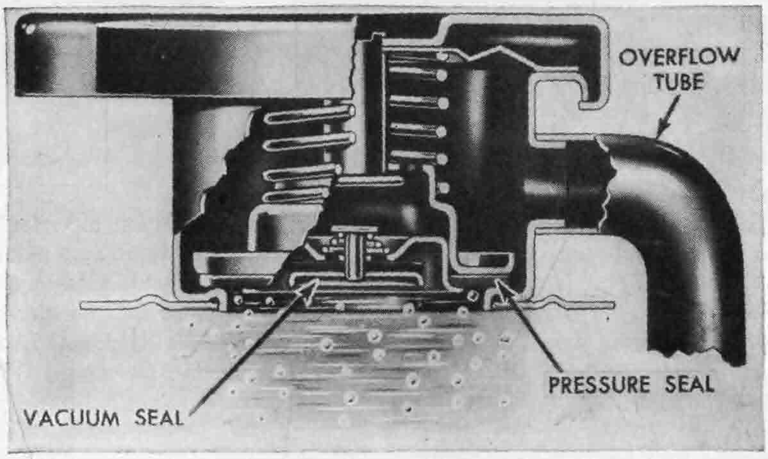


FIG. 13-21. Radiator pressure cap. (*AC Spark Plug Division of General Motors Corporation*)

FIG. 13-22. Cutaway view of radiator pressure cap showing pressure seal valve and vacuum seal valve.



The vacuum valve is designed to prevent the formation of a vacuum in the cooling system when the engine has been shut off and begins to cool. If a vacuum forms, atmospheric pressure from the outside causes the small vacuum valve to open, admitting air into the radiator. Without a vacuum valve the pressure within the radiator might drop so low that atmospheric pressure would collapse it.

§247. Antifreeze solutions Antifreeze solutions are required to prevent freezing of the water when temperatures drop below 32°F. When water freezes in the engine, the resulting expanding force is often sufficient to crack the cylinder block and the radiator. Antifreeze solutions added to and mixed with the water prevent freezing of the mixture. A good antifreeze material must mix readily with water, prevent freezing of the mixture at the lowest temperatures encountered, and circulate freely; it must not damage the cooling system by corrosive action or lose its antifreezing properties after

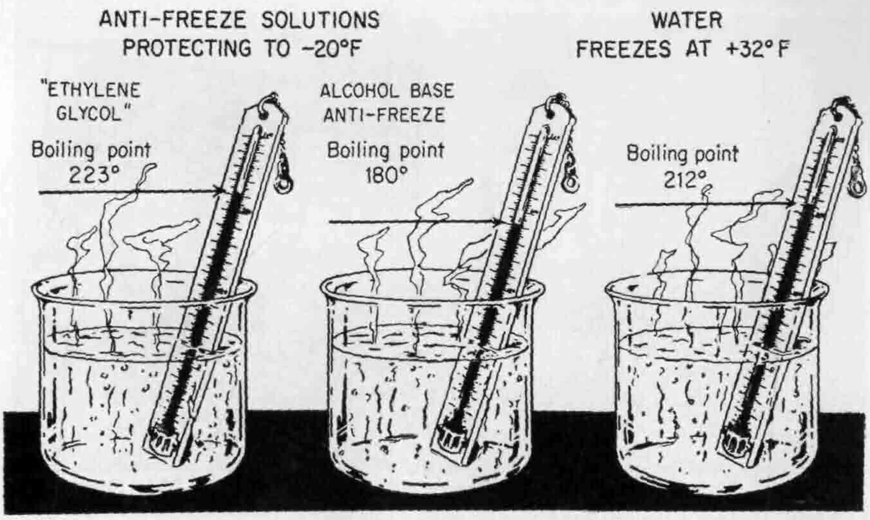


FIG. 13-23. Comparison of boiling points of water and antifreeze solutions.

extended use. In the past a number of different materials have been tried, including salt and sugar solutions, oil, kerosene, and glycerin, but their use has been generally abandoned because of harmful or dangerous effects. The most commonly used antifreeze materials are now either alcohol or alcohol-base, or ethylene glycol. The alcohol-base materials make only temporary antifreeze solutions, since they evaporate at temperatures below the boiling point of water and thus are gradually lost (Fig. 13-23). Such materials may require periodic additions to maintain an antifreeze solution of adequate strength. The ethylene glycol antifreeze materials are of the so-called "permanent" type, since they remain liquid at the boiling point of water.

Antifreeze materials are mixed with water in various proportions according to the expected temperature. The lower the temperature, the higher the percentage of antifreeze material in the solution necessary to prevent freezing of the mixture. Figure 14-7 illustrates a hydrometer used to measure the strength of the antifreeze solution.

§248. Temperature indicators In order that the operator will know at all times the water temperature in the cooling system, a temperature indicator is installed in the car. An abnormal heat rise is a

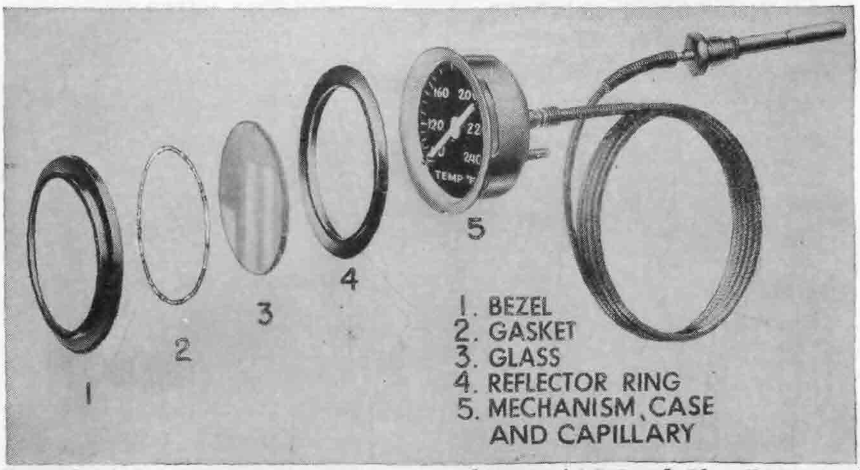


Fig. 13-24. Vapor-pressure temperature indicator. (*AC Spark Plug Division of General Motors Corporation*)

warning of abnormal conditions in the engine; the indicator permits the operator to stop the engine before serious damage is done. Temperature indicators are of two general types, vapor pressure and electric.

1. Vapor Pressure. The vapor-pressure temperature indicator (Fig. 13-24) consists of an indicator bulb and a tube connecting the bulb to the indicator unit. The indicator unit contains a curved or Bourdon tube, one end of which is linked to the indicator needle. The other end is open and is connected through a tube to the bulb. The indicator bulb, usually placed in the water jacket of the engine, is filled with a liquid that evaporates at fairly low temperature. As the engine temperature increases, the liquid in the bulb begins to evaporate, creating pressure that is conveyed through the connecting tube to the Bourbon tube in the indicating unit. The pressure tends to straighten out the tube; the resulting movement causes the indicating needle to move across the dial face and indicate the temperature in the water jacket. This unit is much like the oil-pressure indicator illustrated in Fig. 11-29.

2. *Electric indicators.* Electrically operated temperature indicators are of two types, the balancing-coil type and the bimetal-thermostat type. The balancing-coil type oil-pressure indicator (§222), fuel gauge (§38), and temperature indicator all operate in a similar manner. The dash indicating units are, in fact, practically identical, consisting of two coils and an armature to which a needle is attached (Fig. 13-25). The engine unit changes resistance with temperature in such a way that at higher temperatures it has less resistance and will thus pass more current. When this happens, more current passes through the right-hand coil in the indicating unit, so that the armature to which the needle is attached is attracted by the increased magnetic field. The armature and the needle move around so the needle indicates a higher temperature.

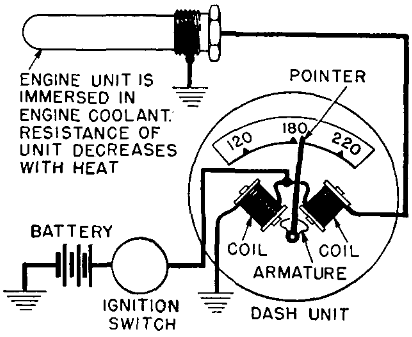


FIG. 13-25. Circuit diagram of electric-resistance temperature-indicator system.

The bimetal-thermostat type of temperature indicator is similar to the bimetal-thermostat fuel gauge (§38). The dash units are practically identical. The engine unit of the temperature indicator, while slightly different in appearance from the tank unit of the fuel gauge, operates in a somewhat similar manner. In the temperature indicator the temperature of the cooling liquid is directly imposed on the engine-unit thermostatic blade. When the temperature is low, most of the blade heating must come from electric current. More current flows, and the dash-unit distorts a considerable amount to indicate a low temperature. As temperature increases, less heat from current flow is required to bring the engine-unit blade up to operating temperature. Less current flows, and the dash unit indicates a higher temperature.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

The cooling system is, of course, essential to the operation of the automotive engine. If it fails to operate properly, the engine will not operate properly; engine failure may result. It is thus important for you to understand how the cooling system operates and how the different component parts that make up the cooling system function. In order to help you remember these essential facts, the following checkup has been included. You can test your memory and find out if you are remembering those facts. At the same time, you will be reviewing the chapter and thereby fixing the important points more firmly in your mind. Write down the answers, since this will help you to remember.

Completing the Sentences

The sentences below are incomplete. After each sentence there are several words or phrases, only one of which will correctly complete the sentence. Write each sentence down in your notebook, selecting the proper word or phrase to complete it correctly.

1. The cooling system removes from the engine *30 to 35* *50 to 60* *85 to 90* percent of the heat produced in the combustion chambers.
2. Included in the forced-circulation system, to assure rapid water circulation, is a *thermostat* *distributing tube* *water pump*
3. Surrounding each cylinder, to assure effective cooling, are water *radiators* *tubes* *jackets*
4. Water pumps used in engine cooling systems are usually of the *expeller* *repeller* *impeller* *compeller* type.
5. Engine fan belts are usually of the *flat* *C* *D* *V* type.
6. Radiators are of two general types, *tube-and-fin and ribbon-cellular* *cylindrical and thermostatic* *distributing-tube and hose*
7. The cooling-system thermostat contains a valve that *opens* *closes* with increasing temperature.
8. The radiator pressure cap has two valves, *intake and vacuum* *blowoff and vacuum* *exhaust and thermostatic*

9. One widely used permanent antifreeze is *ethyl gas* *ethylene glycol* *kerosene* *glycerin*
10. Two types of temperature indicators are *electric and thermostatic* *vapor pressure and electric* *vapor pressure and temperature*

Definitions

In the following, you are asked to write down certain definitions of important terms, purposes of cooling-system components, and so on. The act of writing down these answers in your notebook will help you remember them. It will also make your notebook a more valuable reference for you; you can quickly look up important facts about the automobile that you want to recall.

1. What is the purpose of the cooling system?
2. Why is the thermosiphon cooling system no longer widely used?
3. Where are water jackets located in the engine, and what is their purpose?
4. What is the purpose of the water-distributing tube?
5. Describe the construction and operation of a typical water pump.
6. What is the purpose of the radiator?
7. Describe the construction and operation of the cooling-system thermostat.
8. Describe the construction and operation of the cooling-system radiator pressure cap.
9. What is the purpose of adding antifreeze to the cooling system?
10. Describe the construction and operation of the vapor-pressure type of temperature indicator; the balancing-coil type; the bimetal-thermostat type.

SUGGESTIONS FOR FURTHER STUDY

Examine different engines, radiators, thermostats, and water pumps so that you get a better idea of how the water is circulated in the cooling system. Study the illustrations and descriptions of cooling systems in all the car shop manuals you can find. Study *Automotive Engines* (another book in the McGrawHill Automotive Mechanics Series) for further information on engine thermal efficiency and heat losses. Heat is removed from the engine in several ways; the cooling system is responsible for removing only part of it. You will find further information on this subject in *Automotive Engines*. Be sure to write down any important facts you run across that you want to remember. Write them down in your notebook.

14: Cooling-system service

THIS CHAPTER describes the testing, care, servicing, and repair of automotive-engine cooling systems.

§249. Cooling-system tests Over a period of time, rust and scale accumulate in the radiator and engine water jackets; the rust and scale restrict the circulation of water, and the engine tends to overheat (Fig. 14-1). In addition, the hose and connections between the

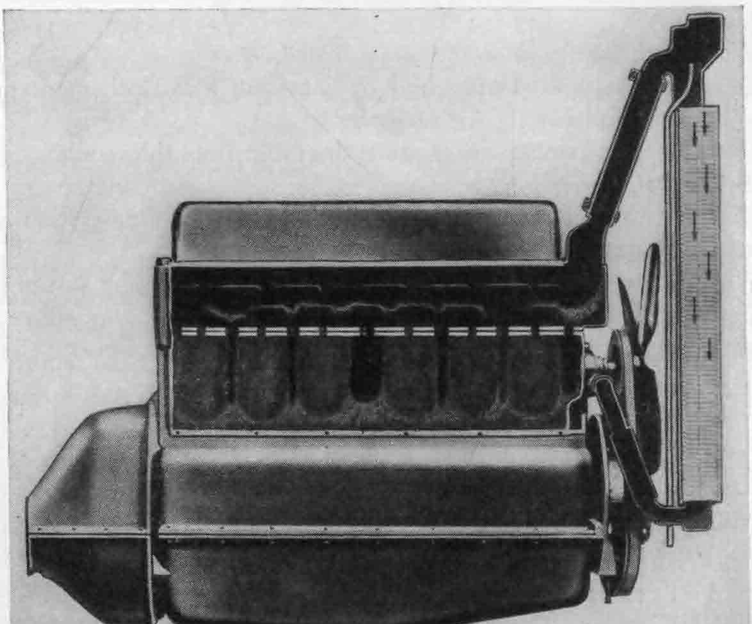


Fig. 14-1. Accumulation of rust and scale in engine water jackets. (*Chevrolet Motor Division of General Motors Corporation*)

radiator and the engine may deteriorate, causing leakage or inadequate passage of water. The thermostat, if stuck or distorted, may not close and open properly and will thus reduce the effectiveness of the cooling system. A number of tests of the cooling system and its components can be made to determine the condition of these parts. In addition, the strength of the antifreeze solution can be tested.

1. *Testing thermostat.* The action of the thermostat can be observed by placing it in a pan of water and heating the pan. A thermometer should be suspended in the water, so that the temperature at which the thermostat starts to open, as well as the full-open temperature, can be determined. The thermostat should not be placed on the bottom of the pan but suspended by a wire or placed on a screen an inch or so above the bottom (see Fig. 14-2). Thermostats are calibrated to operate at various temperatures. If a thermostat does not function according to specifications, it should be replaced.

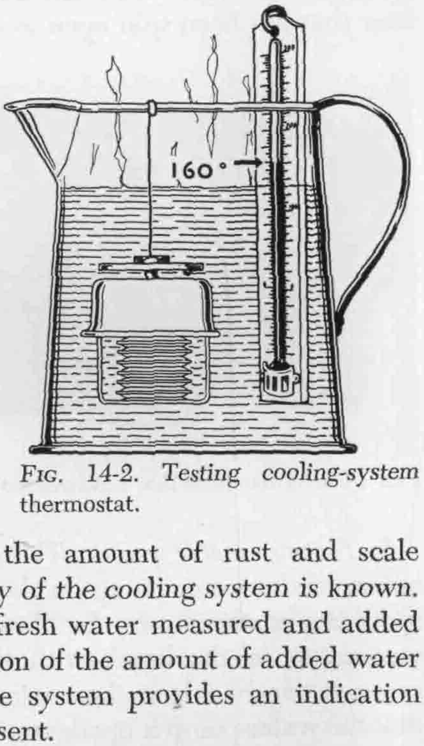


FIG. 14-2. Testing cooling-system thermostat.

2. *Testing system for rust and scale.* The appearance of the water is some indication of whether rust and scale have accumulated in the cooling system. If the water is rusty or muddy in appearance, rust is present. A fairly accurate measurement of the amount of rust and scale present can be made if the capacity of the cooling system is known. All water should be drained and fresh water measured and added until the system is filled. Comparison of the amount of added water with the specified capacity of the system provides an indication of the amount of rust and scale present.

3. *Testing radiator for restriction.* If the radiator hose connections are removed, the radiator drained, and a stream of water from an ordinary garden hose introduced into the top of the radiator, the water should run through the radiator and out without filling up the radiator. If the water runs out slowly, the radiator is clogged. Another test for restrictions in the radiator is to start the engine, allow it to warm up, and then turn the engine off and feel the radiator with the hand. It should be hot at the top and warm at the

bottom, with an even temperature increase from bottom to top. Cold spots indicate clogged sections.

Caution: Be sure the engine is turned off. More than one person has injured his hand seriously by placing it too near an engine fan when the engine was running.

4. *Examining hose and hose connections.* The appearance of the hose and connections will usually indicate their condition. If the hose is rotted and soft and collapses easily when squeezed, it should be replaced. Figure 14-3 illustrates a badly deteriorated section of hose that has been split open to show the internal appearance.

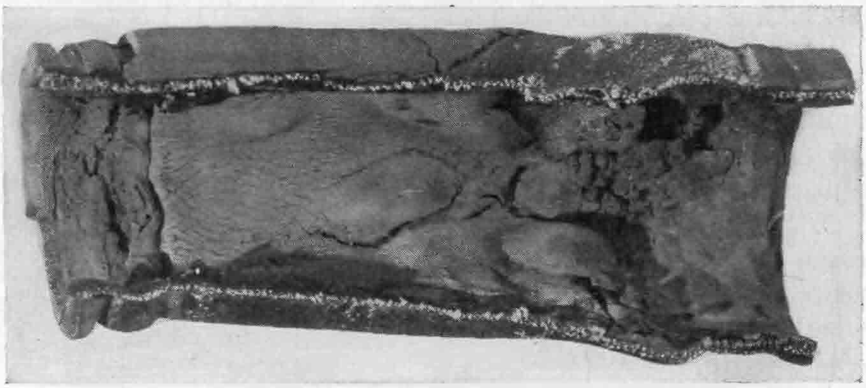


FIG. 14-3. Water hose that has become defective. (*Federal-Mogul Corporation*)

5. *Testing water pump.* There is no accurate way to test the action of the water pump on the car. However, some idea as to its operating condition may be obtained by squeezing the upper hose connection in the hand, with the engine warm and running. If pressure can be felt as the engine is speeded up, it is an indication that the water pump is operating in a normal manner.

6. *Testing for air suction into system.* If leaks exist at any point between the radiator and the water pump, air will be drawn into the system as shown in Fig. 14-4. Air bubbles will cause foaming and loss of the cooling water. The water could, of course, be replaced, but if antifreeze is also lost, then replacement is an expense. There is also the danger of losing antifreeze protection in this way. Air in the system speeds up corrosion and rust. To check for air suction, fill the radiator, attach a hose from the overflow pipe, and

put the lower end of the hose into a container of water, as shown (Fig. 14-4). Start the engine and run it until it is warmed up. If bubbles appear in the container of water, then air is being sucked into the cooling system. (It might be exhaust-gas leakage, as noted in the following paragraph.) Repair by tightening or replacing hose and hose clamps. If this does not cure the trouble, then either

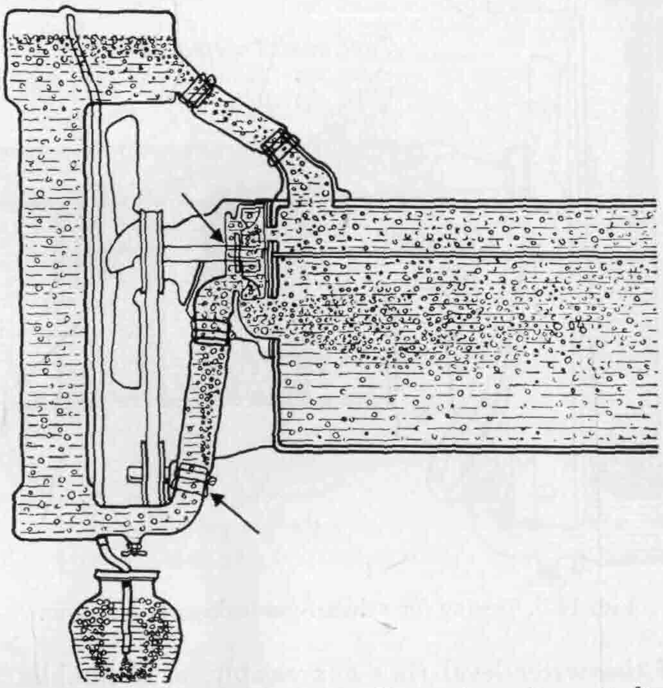


FIG. 14-4. Testing for air suction into cooling system. Arrows indicate points at which air might enter.

there is exhaust-gas leakage or the water pump is leaking. Check the system as noted in the following paragraph. If no exhaust-gas leakage is found, then the trouble is probably in the pump, and it should be repaired (§254).

7. *Testing for exhaust-gas leakage.* A defective cylinder-head gasket may allow exhaust gas to leak into the cooling system. This is very damaging, since strong acids will form as the gas unites with the water in the cooling system. These acids corrode the radiator and other parts in the cooling system. A test for exhaust-gas

leakage may be made by disconnecting the upper hose, removing the thermostat and the fan belt, and draining the system until the water level stands just above the top of the cylinder head (Fig. 14-5). The engine should be started and accelerated quickly several

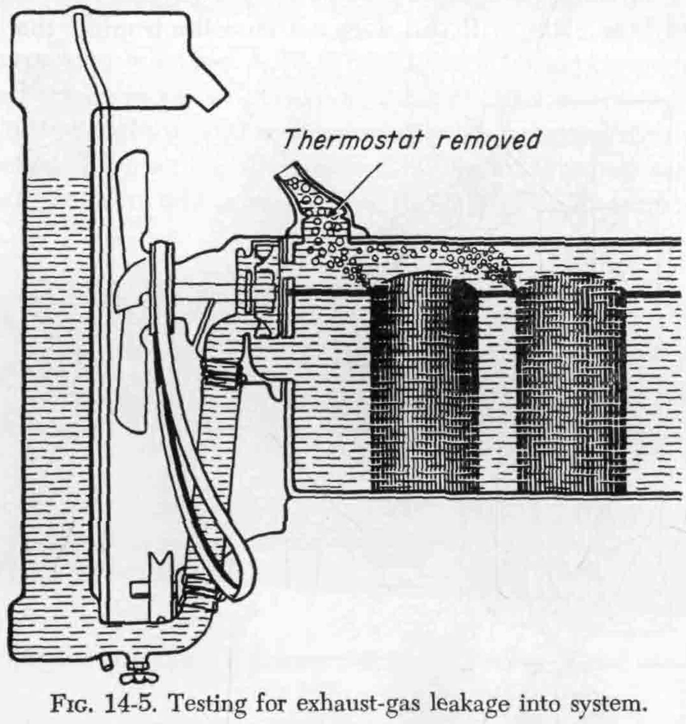


FIG. 14-5. Testing for exhaust-gas leakage into system.

times. If the water level rises appreciably, or if bubbles appear, exhaust gas is leaking into the cooling system. A new gasket should be installed and the cylinder-head bolts properly tightened.

8. *Testing fan belt.* Fan-belt adjustment should be checked by pressing in on the belt (engine not running) halfway between the generator pulley and fan pulley, as shown, for example, in Fig. 14-6. The amount of deflection that the belt will undergo varies with different makes of car. Belt tension is adjusted by loosening the generator mounting clamp screws and moving the generator toward or away from the engine block. The fan belt should be checked every few thousand miles to make sure that it is still in good condition. A belt that has become worn or frayed or that has separated

plies should be discarded and a new belt installed. A defective or loose belt will not only cause overheating of the engine, but may also result in a run-down battery, since it cannot drive the generator fast enough to keep the battery charged.

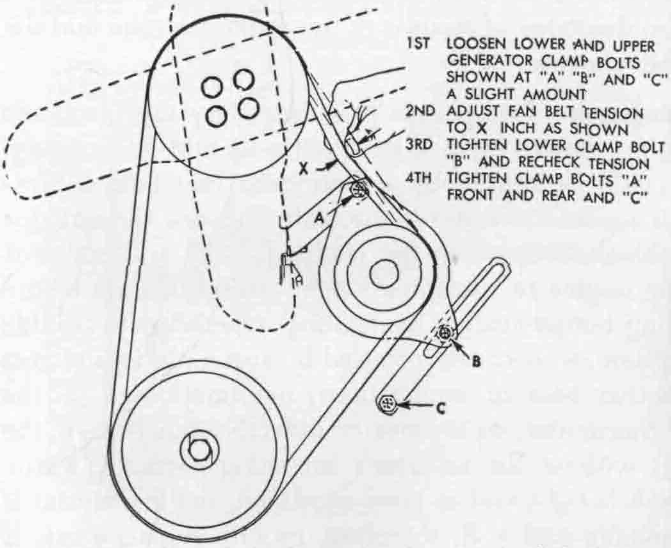


FIG. 14-6. Method of checking and adjusting fan belt on one car. The dimension *X* varies with different models.

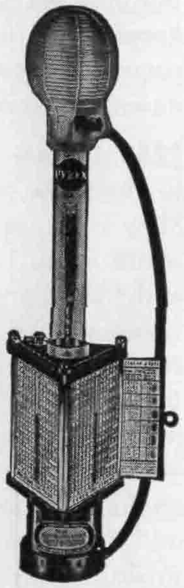


FIG. 14-7. Hydrometer to test antifreeze-solution strength. (*E. Edelmann and Company*)

9. *Testing antifreeze-solution strength.* The strength of the antifreeze solution must not be below that required to furnish adequate protection in the lowest temperatures expected. The strength of the solution is tested by use of a special antifreeze-solution hydrometer (Fig. 14-7), which measures its specific gravity, or heaviness. The so-called "permanent" antifreeze compounds (ethylene glycol) are heavier than water, while alcohol-base antifreeze compounds are lighter than water. The specific-gravity reading will determine what percentage of the solution is water and what percentage is antifreeze compound. Then, by reference to a chart, the lowest

temperature at which the solution will remain a liquid can be determined. Additional antifreeze compound can be added if required.

§250. Care of cooling system Care of the cooling system includes not only normal maintenance operations such as filling the radiator, keeping the fan belt tight, and lubricating the water pump when required, but also diagnosis of trouble in the cooling system and the necessary corrective measures.

§251. *Trouble diagnosis* Complaints that may lead the mechanic to check the cooling system include slow warm-up and overheating. Slow warm-up could be caused by a thermostat that fails and remains open. This causes the water to circulate between the radiator and the engine block, even when the engine is cold, and makes it necessary for the engine to run for a longer period of time before reaching operating temperature. Overheating, when due to trouble in the cooling system, is most often caused by accumulations of rust and scale, defective hose or connections, malfunctioning of the water pump or thermostat, or a loose or defective fan belt. If the engine overheats without the radiator's becoming normally warm, and if the fan belt is tight and in good condition, the thermostat is probably not opening and will, therefore, require replacement. If the radiator is hot, test the water pump by pinching closed the upper hose by hand as described in §249. If the thermostat and water pump seem to be operating normally and the hose appears to be in good condition, the overheating, if actually caused by troubles in the cooling system, is probably due to accumulations of rust or scale in the cooling system. Such rust or scale should be cleaned and flushed out (§252). The water may boil after the engine has been turned off; this is called *after boil.* This could happen, for example, after a long, hard drive. The engine has so much heat in it (though it has not actually overheated) that after the engine is turned off, the water in the cooling system boils (Fig. 14-8), due to the fact that it is still absorbing heat from the engine, which it cannot get rid of because the cooling system is no longer working.

Boiling can also occur if the radiator has frozen up. This hinders or stops the circulation of the cooling water. Consequently, the water in the water jackets becomes so hot that it boils.

It must be remembered that there are other causes of engine overheating, which have nothing to do with conditions in the cooling system. High-altitude operation, insufficient oil, overloading of the engine, hot-climate operation, improperly timed ignition, long periods of low-speed or idling operation—any of these may cause overheating of the engine. See *Automotive Engines* (another book in the McGraw-Hill Automotive Mechanics Series) for more information on overheating of engines.

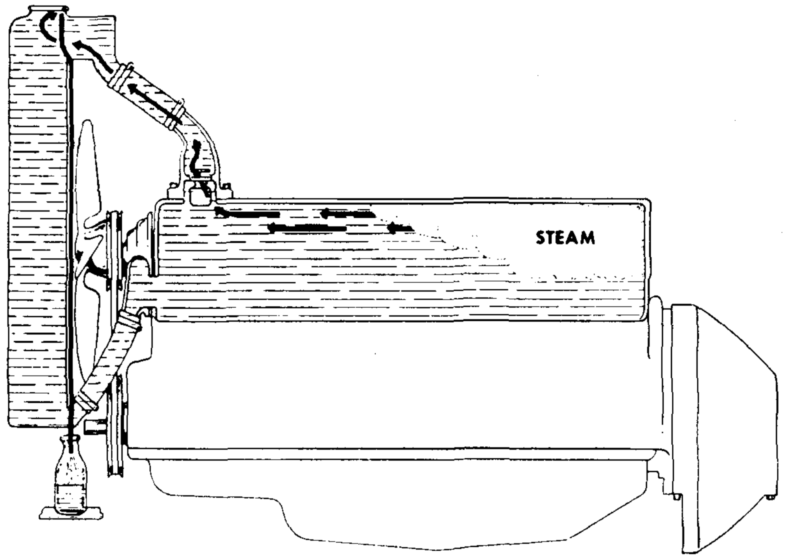


FIG. 14-8. After-boil of water after engine is stopped.

§252. Cleaning the cooling system The cooling system should be cleaned at periodic intervals to prevent the accumulation of excessive rust and scale. Accumulated rust and scale can be loosened by a good cleaning compound. There are various types of cleaning compounds; all must be used carefully in accordance with the manufacturer's instructions. A general cleaning procedure is outlined below. If considerable scale and rust have accumulated, it may be that cleaning alone will not remove it all. In this case, the radiator and engine water jackets must be flushed out with special heater can be flushed out at the same time (Fig. 14-11). Some car air-pressure guns as shown in Figs. 14-9 and 14-10. The hot-water manufacturers recommend reverse flushing; that is, the water is forced through the radiator and water jackets in the opposite

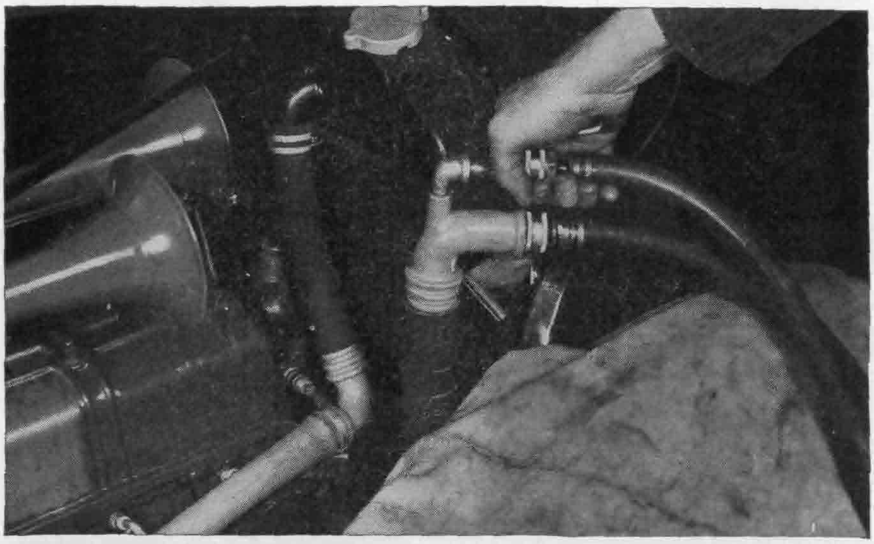


FIG. 14-9. Reverse flushing of radiator. (*Kent-Moore Organization, Inc.*)

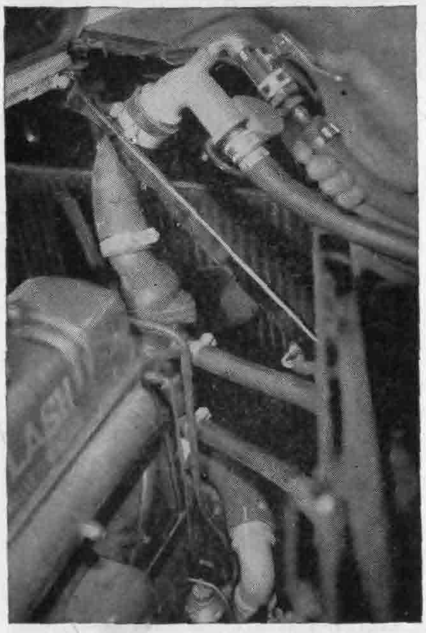


FIG. 14-10. Reverse flushing of engine water jackets. (*Kent-Moore Organization, Inc.*)

direction to that in which the water normally circulates. This gets behind the scale and loosens it so that it will be flushed out.

1. Cooling-system cleaning procedure. Completely drain the system by opening drain cocks (Fig. 14-12). Add cleaning compound and fill system with water. Run engine on fast idle for at least 30 minutes after engine reaches operating temperature. Completely drain system again, add neutralizer (if cleaner requires its use), fill with water, and run engine at fast idle for at least 5 minutes. Drain system, refill with water, and run for at least 5 minutes after water has reached operating temperature. Then

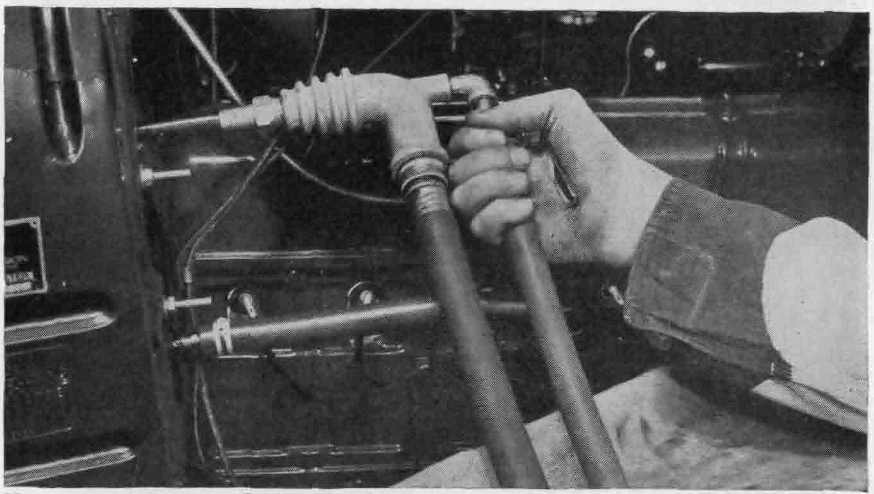


FIG. 14-11. Reverse flushing of hot-water heater. (*Kent-Moore Organization, Inc.*)

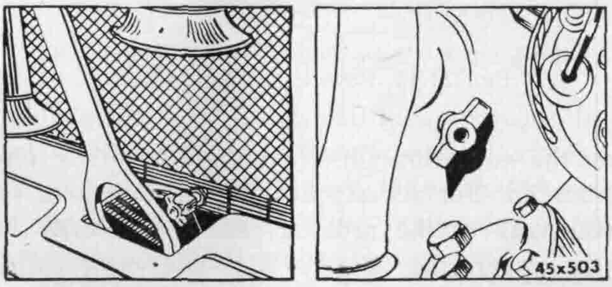


FIG. 14-12. Locations of drain cocks in radiator and engine block on one car. (*Plymouth Division of Chrysler Corporation*)

drain and refill once again, this time with antifreeze (if it is to be used).

NOTE: During the procedure, keep the radiator covered so engine develops as much heat as possible. Otherwise, the engine might not get hot enough to make the thermostat open wide. This would slow water circulation and reduce the cleaning effect.

2. *Cleaning radiator air passages.* At the same time that the cooling system is cleaned, the radiator air passages should be cleaned out. This can be done by blowing them out, from back to front, with compressed air. This removes bugs, leaves, and dirt that could clog the air passages and reduce the cooling efficiency of the radiator.

3. *Flushing radiator.* If cleaning alone does not remove all the accumulated rust and scale, the radiator and water jackets should be flushed. This job is done with a flushing gun that uses air pressure to force the water through. The radiator can be straight-flushed or reverse-flushed. For reverse flushing, a new hose is attached to the lower tank of the radiator, and a leadaway hose is attached to the upper tank (Fig. 14-13). The water will, of course, drain out as this is done. Clamp flushing gun in hose to lower tank, as shown, and turn on water to fill radiator. When water runs out the leadaway hose, apply air pressure to force water out. Apply the pressure gradually, to avoid damaging the radiator. Sudden full-pressure application might rupture the radiator core. Refill radiator and again apply air pressure. Repeat until water running from leadaway hose is clean.

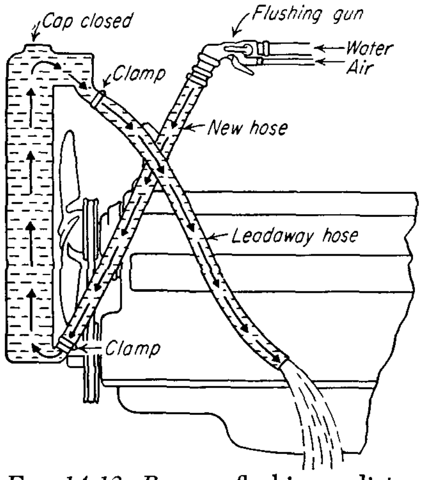


FIG. 14-13. Reverse-flushing radiator.

To straight-flush the radiator, follow the above procedure but attach leadaway hose to the lower tank of the radiator and the flushing-gun hose to the upper tank. This will circulate the water through the radiator in the normal direction.

4. *Flushing engine water jackets.* Engine water jackets also may be straight-flushed or reverse-flushed. Some engine manufacturers warn that seals and other engine parts may be damaged if their engines are reverse-flushed. Make sure the specifications permit reverse flushing before doing the job. To reverse-flush, remove the thermostat and attach the flushing gun to the thermostat housing with a short length of hose (Fig. 14-14). The illustration does not show a leadaway hose from the water-pump inlet, but to avoid getting water all over the engine, it is best to use a leadaway hose.

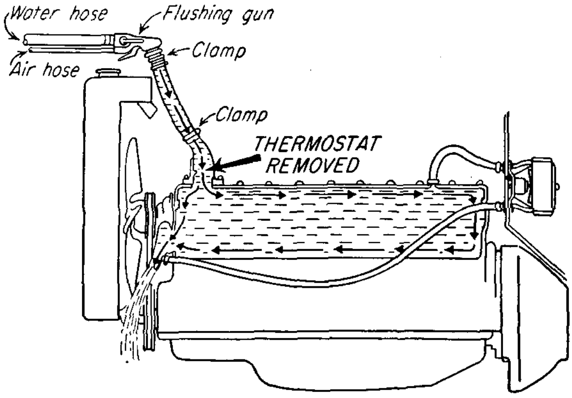


FIG. 14-14. Reverse-flushing engine water jackets.

Fill the water jackets with water, and then apply air. Repeat as for the radiator until the water runs clear from the leadaway hose.

To straight-flush the water jackets, follow the above procedure, but attach the leadaway hose to the thermostat housing and the flushing-gun hose to the pump-inlet connection.

Caution: Do not apply too much air pressure or sudden bursts of pressure. This might damage engine seals, gaskets, or other parts.

5. *Refilling system.* When the cooling system has been cleaned, the thermostat replaced, and all hoses and clamps reconnected, the system should be refilled. Since the water that is put in will probably be cold, the thermostat may close and prevent quick filling. With the thermostat closed, air is trapped below the thermostat in the engine water jackets (Fig. 14-15). The thermostat usually has

a small hole or two that permits this air to leak out. But it takes a little time for the air to escape. This means that you may have to fill and refill the radiator several times, waiting each time for some of the trapped air to get out. Then, as a final step, the engine should

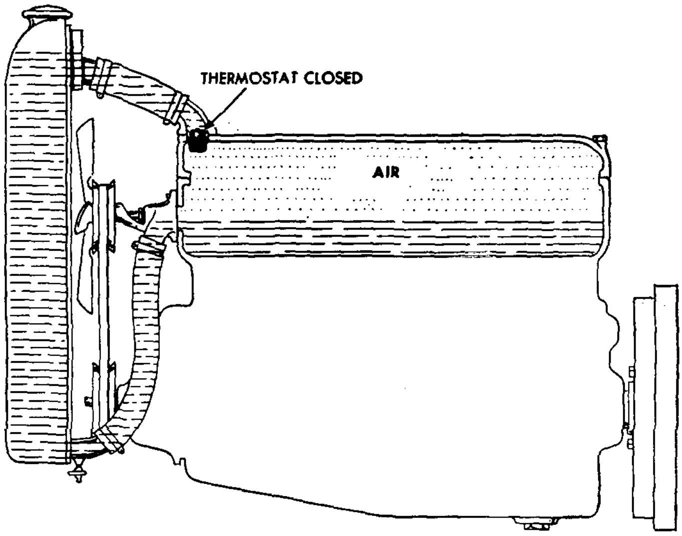


FIG. 14-15. Air trapped back of closed thermostat as engine cooling system is filled.

be started and run long enough for the thermostat to heat up and open. After this happens, more water can be added to make sure the system is filled.

§253. Locating and repairing radiator leaks Leaks in the radiator core are usually obvious, since telltale scale marks or watermarks will form on the outside of the core below the leaks. An accurate way to locate radiator leaks is to remove the core from the car, drain out all the water, close the openings at top and bottom, and immerse the core in water. Air bubbles will escape from the core through any leaks. Small leaks may sometimes be repaired without removing the radiator from the car, by use of certain liquid compounds poured into the radiator. These compounds, seeping through the leaks, harden upon coming in contact with the air, sealing off the openings. A more effective way of repairing leaks is to solder them. If there are several leaks at various places in the core, it may not be worthwhile to attempt repair, since the core is probably corroded to a point where other leaks would soon develop.

Removing a radiator core is a relatively simple job although there is a considerable amount of work involved. The procedure varies somewhat from car to car but, in general, is as follows. First, drain the engine and radiator by opening the drain cocks in the radiator and engine block. Figure 14-12 shows the locations of these two cocks on one car. Locations vary somewhat from one make to another. With the cooling system drained, detach the upper and lower radiator hoses. Remove any support bolts, horns, wiring harness, and so forth, that might interfere with core removal. With these parts out of the way and the core loose, lift it straight up and off the car.

§254. Water-pump service The water pump is a relatively simple mechanism which requires little service in normal operation. Some pumps require periodic lubrication; others, with sealed ball bearings, require no lubrication. If the pump develops noise or leaks or becomes otherwise defective, it must be removed for repair. The procedures of removal, repair, and replacement vary for different cars. Typical procedures follow.

1. Chevrolet. To remove water pump, drain cooling system by opening drain cocks, disconnect hose from pump, remove fan belt, take out pump attaching screws, and lift off pump.

a. To disassemble pump, take off fan, pump-plate attaching screws, and pump plate.

b. Then use special puller to pull fan pulley from pump shaft (Fig. 14-16). It is very important to use this tool correctly in order not to damage the pulley, shaft, or bearing. Note particularly that the puller plate should be square with the pulley face.

c. With the pulley off, put the pump in a vise, and use a long drift punch to remove bearing retainer from pump body.

d. Then, with large end of pump up, put pump on arbor press with pump supported on the milled shoulder of the pump body. Use arbor slightly smaller than diameter of pump shaft, and press shaft and bearing assembly out of the pump body and rotor. Lift rotor from pump body, and discard the old seal assembly.

e. Before inspecting the pump parts, wash all parts except the pump-shaft bearing in cleaning solvent. Do not wash the bearing in solvent since this would remove the sealed-in lubricant and ruin the bearing. If the shaft seems loose in the bearing assembly, the assembly should be replaced. The thrust-washer

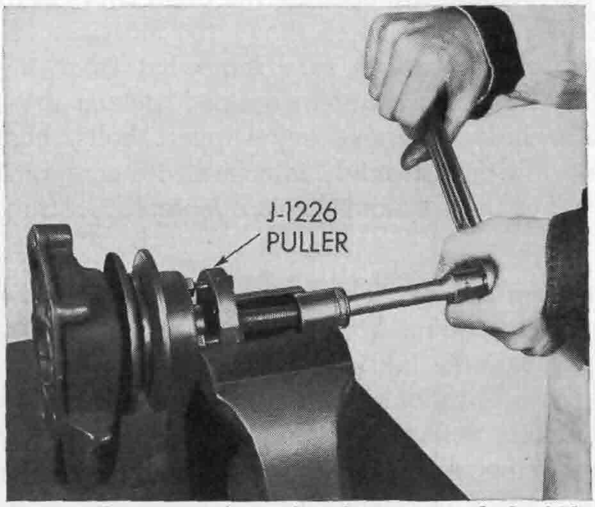


FIG. 14-16. Using puller to pull fan pulley from pump shaft. (*Chevrolet Motor Division of General Motors Corporation*)

seat in the pump body should be smooth and even. If pitted or scored, the pump should be replaced.

f. To reassemble the pump, first install the pump shaft and bearing assembly in the pump body, applying pressure to the outer race of the bearing. Press in until the outer race bottoms. Do not press on the shaft since this might damage the bearing.

g. Then use a short piece of 1½-inch (inside diameter) pipe to press (in arbor press) the bearing retainer into position on the pump body and bearing.

h. Examine rubber seal to find the side without the three projections. Cover this side with sealer, and place seal in rotor bore with the sealer-coated side down. Coat both sides of thrust washer with a small amount of water-pump grease, and put washer on top of seal assembly so that the two lugs index with slots in rotor. Lay rotor and seal assembly on bed of arbor press, and press shaft and housing assembly down over rotor. Press on shaft.

i. Check clearance between face of rotor and pump body (Fig. 14-17). It should be 0.010 to 0.035 inch.

j. Then press pulley onto shaft in arbor press until pulley is flush with end of shaft.

k. Install pump plate on body with new gasket. Tighten and stake attaching screws. Install fan.

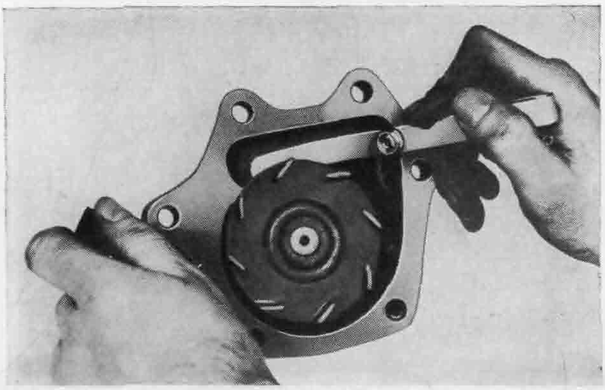


FIG. 14-17. Measuring clearance between face of rotor and pump body. (*Chevrolet Motor Division of General Motors Corporation*)

2. *Plymouth.* To remove the water pump, drain the cooling system by turning the drain cocks (Fig. 14-12), disconnect hose, remove fan belt, and take out attaching screws so pump can be lifted off.

a. For disassembly, refer to Fig. 14-18.

b. Take off fan, and drive out the pin from the fan-pulley hub.

c. Remove the water-pump cover, and pull the impeller and shaft out.

d. If necessary, remove the bushings by driving the front bushing pin into the shaft hole and then using special tool to force bushings out (Fig. 14-19).

e. Any parts showing wear should be discarded. Always use a new seal and retaining washer on reassembly. If the seal seat in the pump body is scored or rough, it should be refaced with special tool (Fig. 14-21).

f. To reassemble the pump, first insert a new thrust washer in the pump body, flat side facing the fan-pulley hub.

g. Press new bushings into body (if old were removed) with special tool shown in Fig. 14-19. The special tool will assure installation of the inner bushing to a recessed depth of $\frac{9}{64}$ inch as shown in Fig. 14-20.

h. Drill hole in front bushing as shown in Fig. 14-20 with No. 13 drill, and drive in pin. Be sure all burrs are removed from inside of bushing.

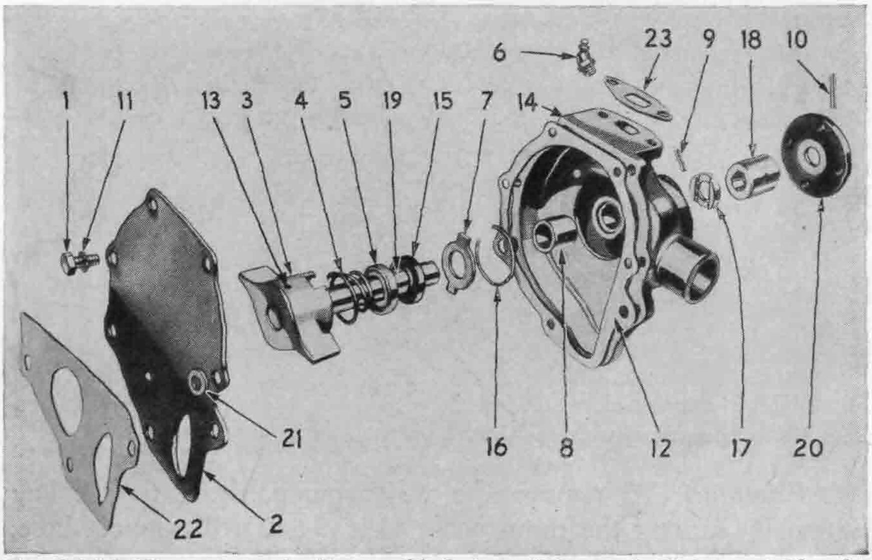


FIG. 14-18. Water pump in disassembled view. (*Plymouth Division of Chrysler Corporation*)

1. Body-cover-plate screw
2. Body-cover plate
3. Impeller
4. Seal-thrust spring
5. Seal retainer
6. Lubricant nipple
7. Seal-retainer washer
8. Shaft rear bushing
9. Shaft-front-bushing pin
10. Fan-pulley hub pin
11. Body-cover-plate screw lock washer
12. Body-cover-plate gasket
13. Impeller pin
14. Body
15. Seal
16. Seal-retainer-washer lock ring
17. Shaft thrust washer
18. Shaft front bushing
19. Shaft
20. Fan-pulley hub
21. Body-cover-plate screw washer
22. Cover plate to cylinder-block gasket
23. Bypass elbow gasket

i. Use special tool to burnish bearings, and reface the seal seat in the pump body (Fig. 14-21).

j. Then assemble seal parts in the impeller. Place special tool on shaft so seal will slide on to shaft without being damaged.

k. Install seal retainer washer and grease retainer washer on shaft, compress the seal assembly as far as possible, and install the lock ring. Insert the complete assembly into the pump body as far at it will go.

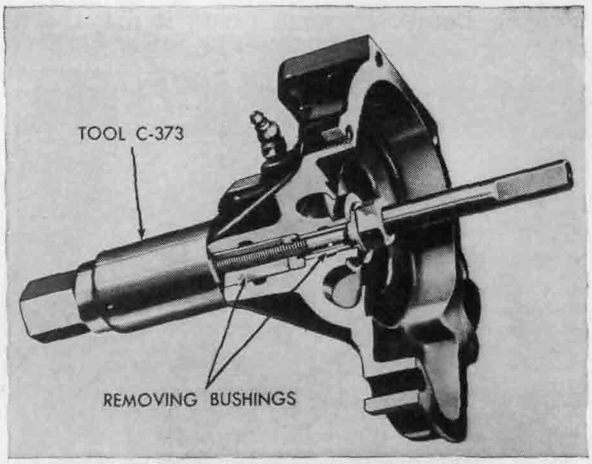


FIG. 14-19. Removing bushings from water pump with special tool. (*Plymouth Division of Chrysler Corporation*)

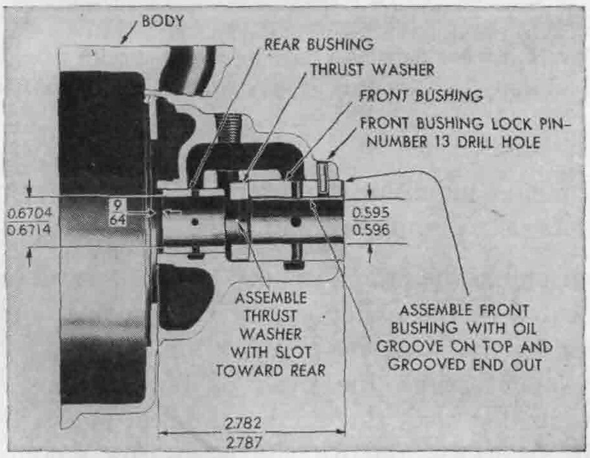


FIG. 14-20. Locations and measurements of bushings in water pump. (*Plymouth Division of Chrysler Corporation*)

l. Make sure the flat spots on the shaft interlock with the flats of the thrust washer. Press the hub onto the shaft, leaving 0.003-inch (or between 0.0005- and 0.005-inch) clearance between the front bushing and hub.

m. Drill a hole through the hub and shaft, and install pin. Peen over ends of pin so it will hold.

3. *Ford.* To remove the water pump (Fig. 14-22), drain the cooling system, disconnect hose, take off fan belt, remove mounting bolts, and take off pump. In some cases, it may be necessary to

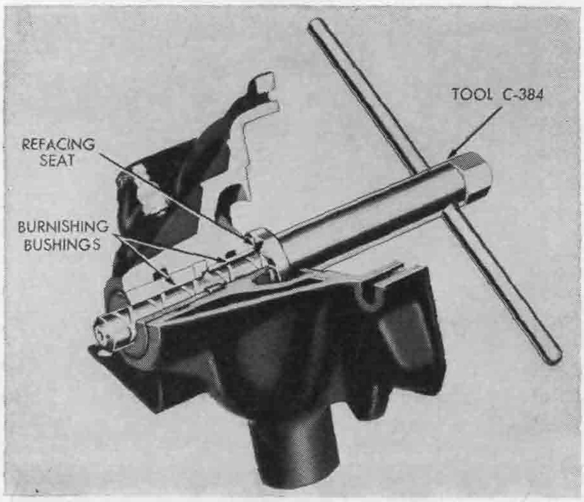


FIG. 14-21. Burnishing bushings and refacing seal seat with special tool. Housing has been cut away to show tool. (*Plymouth Division of Chrysler Corporation*)

loosen the engine mounting bolts and raise the engine so that mounting bolts clear pump attaching bolts.

a. To disassemble the pump, remove the pulley and bearing lock ring located at the pulley end of the housing, and press the impeller off the shaft by pressing the shaft and bearing assembly out through the front of the housing. Use arbor slightly smaller than shaft. Press the seal out of the housing and, if necessary, remove the snap ring from inside the housing.

b. To assemble the pump, replace the snap ring inside the housing, and press a new seal into the housing with the carbon washer of the seal facing the impeller. Use special seal replacer tool, and make sure it contacts only the outer metal part of the seal. Otherwise the carbon sealing washer may be damaged. Position the slinger on the shaft with the flanged end toward the bearing, and insert the shaft and bearing assembly into the housing at the front end. Press the shaft and bearing assembly into the housing, using special hollow tool to exert pressure on the outer bearing race only. Do not press on the shaft; this will damage the bearing. Install the bearing lock ring in the groove in the housing. Press pulley onto the shaft,

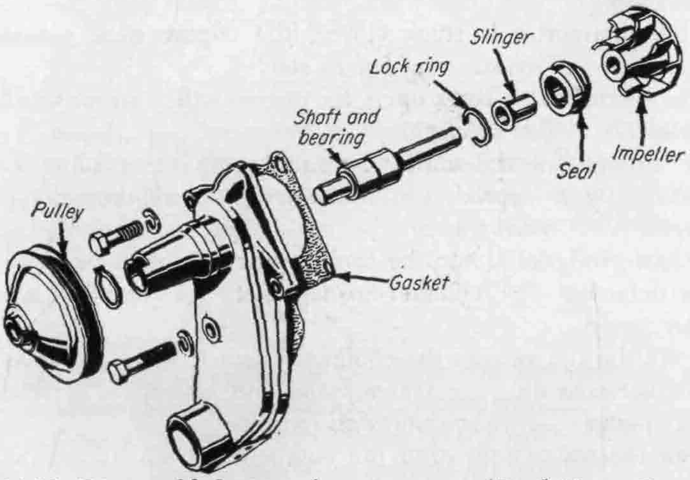


FIG. 14-22. Disassembled view of water pump. (*Ford Motor Company*)

and press impeller on shaft to proper position. Clearance between the impeller blades and housing should be between 0.031 and 0.040 inch.

CHAPTER CHECKUP

NOTE: Since the following is a chapter review test, you should review the chapter before taking the test.

Here is your checkup on the final chapter of the *Automotive Fuel, Lubricating, and Cooling Systems* book. You have made wonderful progress in your studies of this book and must feel proud at having "stuck to it" until you finished it. The information you have learned from the book gives you the basic background you need to become a specialist in the engine systems discussed, or to become a good, all-around automotive mechanic. Take the checkup that follows to make sure you have the essential facts in the chapter well in mind. Write down your answers in your notebook.

Picking Out the Right Answer

Several answers are given for each question or statement below. Read each statement carefully; then decide which of the several answers that follow is the correct one. Write down the completed statement or answered question in your notebook.

1. Accumulation of rust and scale in the engine-cooling system will cause *slow warm-up* *reduced heating capacity* *overheating*
2. If the thermostat is stuck closed, the engine will *warm up slowly* *overheat* *fail to start*
3. If the thermostat is stuck open, the engine will *warm up slowly* *overheat* *fail to start*
4. The strength of the antifreeze solution in the cooling system is checked by a special *micrometer* *hydrometer* *barometer* *thermometer*
5. Exhaust-gas leakage into the cooling system is most likely to be due to a defective *cylinder-head gasket* *manifold gasket* *water pump*
6. Air will be drawn into the cooling system if there are leaks at any point between the *water pump and jackets* *radiator and water pump* *thermostat and radiator*
7. When the water boils after the engine has been turned off after a hard run, the condition is known as *overheating* *hard running* *clogged radiator* *after-boiling*
8. When reverse-flushing the radiator, the flushing gun is connected to the *upper tank* *pump inlet* *lower tank*
9. When reverse-flushing the engine water jackets, the flushing gun is connected to the *upper tank* *lower tank* *thermostat housing* *pump inlet*
10. When refilling the system with cold water causes the engine to be cooled, air may be trapped *below the thermostat* *above the thermostat* *in the radiator*

Correcting the Lists

In each of the lists below, you will find one item that does not belong. Write down each list in your notebook, but do not write down the item that does not belong.

1. Engine overheating can be caused by: accumulations of rust and scale, thermostat stuck closed, thermostat stuck open, loose fan belt, defective hose, defective water pump

2. Slow engine warm-up can be caused by: thermostat stuck open, manifold heat-control valve stuck, thermostat stuck closed
3. Tests of the cooling system include testing the: thermostat, radiator (for restrictions), hose and hose connections, water pump, fuel pump, fan belt, antifreeze strength
4. Items in the cooling system that can be flushed with the flushing gun include the: radiator, engine water jackets, filter, car heater
5. Boiling of the water can occur due to: radiator freezing, after-boil, thermostat stuck closed, high-altitude operation, broken fan belt, thermostat stuck open

Procedures

In the following, you are asked to write down certain servicing procedures or to list various troubles and explain them. Write these down in your notebook. The act of writing them down not only helps you remember the important points, but also makes your notebook a very valuable reference, in which you can look up things that might have escaped your memory for the moment.

1. How is the thermostat tested?
2. How can the cooling system be tested for rust and scale?
3. How can you check the radiator for restrictions?
4. How can the water pump be checked on the car?
5. How can the system be tested for exhaust-gas leakage?
6. How is the fan belt adjusted?
7. How is the strength of the antifreeze solution tested?
8. What conditions in the cooling system will cause engine overheating?
9. What condition in the cooling system would cause slow engine warm-up?
10. Describe how a cooling system is flushed out.
11. Describe how to remove a radiator core, locate a leak, and repair the leak.
12. Describe step by step, how to remove a water pump from a car, disassemble, inspect, and reassemble it.

SUGGESTIONS FOR FURTHER STUDY

Watch how the mechanics at the automotive service shop clean out cooling systems and take off radiators and water pumps. Notice how they tear down and repair water pumps and what special equipment they need for this job. Study car shop manuals of the various makes of cars, and notice the different methods of repair these manuals recommend. Write down in your notebook any important facts you run across in the manuals or in the shop.

Appendix A: Exhaust-gas Analyzers

EXHAUST-GAS ANALYZERS are devices that are used to determine the proportions of the fuel and air entering the combustion chamber by analyzing the exhaust gas produced by combustion of the fuel and air. The gases found in the exhaust from the combustion chamber vary according to the proportions of gasoline and air that entered into the combustion. Three types of exhaust-gas analyzer are in use: the thermal-conductivity, hot-wire-catalysis, and relative-density.

1. Thermal conductivity "Thermal conductivity" is a term that expresses the ease with which heat is conducted through a substance. Some substances allow heat to pass through readily; others, such as asbestos, resist its passage. The various gases found in exhaust gas have

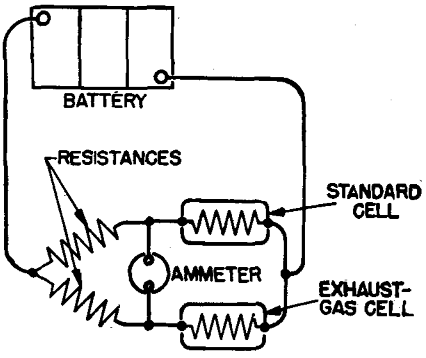


FIG. *A*-1. Schematic wiring diagram of a thermal-conductivity tester for testing exhaust gas.

varying degrees of thermal conductivity and pass heat with varying degrees of ease. Thus measurement of the thermal conductivity of the exhaust gas will accurately determine the proportions of carbon dioxide, carbon monoxide, hydrogen, and oxygen in the exhaust gas. These proportions depend on the air-fuel ratio that is delivered to the engine.

The thermal-conductivity tester (Fig. *A*-1) consists of a battery, two resistances, a sensitive ammeter (or galvanometer), and two cells in which are suspended platinum-wire spirals. The flow of current through the two spirals heats them, and they increase in temperature until they stabilize; that is, until the heat they give off balances the heat created in them by the current flow. The heat they give off travels through the intervening air to the walls of the cells. When the air surrounding the two spirals is identical, the two spirals will stabilize at the same temperature and will thus be drawing the same amount of current. If air of a different thermal conductivity is introduced into one cell, the spiral in that cell will stabilize at a different temperature. Since the resistance of platinum wire varies with temperature, that spiral will now pass a different amount of current. This means that the ammeter, which reads zero when both circuits pass the same amount of current, now begins to register the difference in current flow in the two circuits. This is because part of the current now passes through the ammeter in order to flow through the platinum wire having the lower resistance. The application of this principle to exhaust-gas analysis is obvious. Air is introduced into the standard cell, while exhaust gas passes through the exhaust-gas cell. The difference in thermal conductivity between the two is indicated by the ammeter reading. The ammeter dial is usually marked off to read air-fuel ratio directly, so that no calculations are necessary.

2. Hot-wire catalysis In some respects, the hot-wire-catalysis exhaust-gas analyzer (Fig. *A*-2) is similar to the thermal-conductivity analyzer.

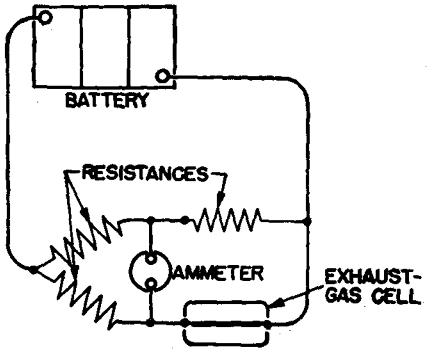


Fig. *A*-2. Schematic wiring diagram of a hot-wire-catalysis exhaust-gas analyzer.

Both make use of a platinum wire heated by electric current and a sensitive ammeter that records difference in resistance in two parallel circuits. The hot-wire catalysis, however, uses a single straight platinum wire enclosed in a cell. The resistances are so balanced that the same amount of current is passing through each side of the two parallel circuits. The current passing through the straight platinum wire in the exhaust-gas cell heats the wire to a red heat. Under this condition, and before the test begins, the ammeter registers zero. Exhaust gas, mixed with a definite ratio of air, is then passed through the exhaust-gas cell.

Any unburned components in the exhaust gas now have another chance to burn as they pass the red-hot wire. They do burn, and this further raises the temperature of the wire. The more unburned components in the exhaust gas, the more combustion, and the higher the temperature of the wire. This increase of temperature causes an increase in resistance and a consequent reduction of current flow in the platinum wire. The ammeter registers this difference of current flow, since it will pass current seeking to flow through its resistance rather than through the wire. The ammeter dial is marked off to read air-fuel ratio directly.

3. Relative density The density of the exhaust gas is determined by the proportions of its various components, each of which has a different density. Thus, by determining the density of the exhaust gas, the result can be evaluated in terms of the air-fuel ratio. The type of analyzer that measures the density of the exhaust gas relative to air consists of two fans rotated in two chambers by a motor. Both rotate at the same speed; one in air, the other in exhaust gas. The air or gas movement produced by the fans causes two impulse wheels to move. The two impulse wheels are linked together, and one of them has a pointer registering on a dial. Since the exhaust gas is heavier or denser than air, the impulse wheel in the exhaust-gas chamber will turn more than will the impulse wheel in the air chamber. This causes the pointer to move across the dial and register directly the air-fuel ratio that produced the exhaust gas.

Appendix B: Glossary

THIS GLOSSARY of automotive terms used in the book is designed to provide a ready reference for the student. The definitions may differ somewhat from those given in a standard dictionary; they are not intended to be all-inclusive, but have the purpose of serving as reminders so that the student can quickly refresh his memory on automotive terms of which he may be unsure. More complete definitions and explanations of the terms are found in the text.

Abrasive In automobile service, a substance used for cutting, grinding, or polishing metal.

Accelerator The foot-operated pedal linked to the carburetor throttle valve.

Accelerator pump In the carburetor, a pump linked to the accelerator, which momentarily enriches the mixture when the accelerator pedal is depressed.

Air bleed An opening into a gasoline passage through which air can pass (or bleed) into the gasoline as it moves through the passage.

Air cleaner The device mounted on the carburetor, through which air must pass on its way into the carburetor air horn. It filters out dirt and dust particles and also silences the intake noise.

Air-cooled engine An engine that is cooled by passage of air around the cylinders and not by passage of a liquid through water jackets.

Air-fuel mixture Mixture delivered to engine by carburetor.

Air horn In the carburetor, the tubular passage through which the incoming air must pass.

Air line A hose or pipe through which air passes.

Air pressure Atmospheric pressure (14.7 psi at sea level) or pressure of air produced by pump, by compression in engine cylinder, etc.

Antifriction bearing Type of bearing in which moving parts are in rolling contact; ball, roller, or tapered roller bearing.

Antiknock In engine fuels, the property that opposes knocking.

Antipercolator The device in the carburetor that opens a vent when the throttle is closed, to permit release of fuel vapors in the high-speed circuit so that fuel vapor will not push fuel out of the high-speed nozzle.

Atmospheric pressure Pressure of the atmosphere, or air, due to its weight pressing downward. Average is 14.7 psi at sea level.

Appendix B: Glossary

Atomization The spraying of a liquid that makes it a very fine mist.

Automatic choke A choke that positions the choke valve automatically in accordance with engine temperature.

Backfiring Pre-explosion of air-fuel mixture so that explosion passes the still-opened intake valve and flashes back through the intake manifold.

Balanced carburetor Carburetor in which the float bowl is vented into upper air horn, below air cleaner, to eliminate effects of clogged cleaner.

Ball check valve A valve consisting of a ball and seat. Fluid can pass in one direction only; when it attempts to flow the other way, it is checked by the ball seating on the seat.

Barrel The air horn in the carburetor; used particularly to refer to that part of the air horn in which the throttle valve is located.

BDC Bottom dead center, which see.

Bearing Generally, the curved surface on a shaft or in a bore, or the part assembled onto one or into the other to permit relative rotation with minimum wear and friction.

Bellows A device, usually metal, that can lengthen or shorten much like an accordian. The thermostat in the cooling system is usually a bellows.

Bimetal Referring to the thermostatic bimetal element made up of two different metals with different heat-expansion rates; temperature change produces a bending or distorting movement.

Blow-by Leakage of compressed air-fuel mixture or burned gases from the combustion chamber, past the piston rings, and into the crankcase.

Body The assembly of sheet-metal sections, together with windows, doors, seats, and other parts, that provides an enclosure for the passengers, engine, etc.

Borderline knock test A test used to establish octane rating, or knock resistance, of different fuels.

Borderline lubrication Type of lubrication resulting when greasy friction exists. Moving parts are coated with a very thin film of lubricant.

Bore Diameter of engine cylinder hole; also may be diameter of any hole, as, for instance, the hole in which a bushing fits.

Bottom dead center The piston position at which the piston has moved to the bottom of the cylinder and the center line of the connecting rod is parallel to the cylinder walls.

Brake horsepower The power delivered by the engine which is available for driving the vehicle.

Breather The opening that allows air to circulate in the crankcase and that is part of the *crankcase ventilator,* which see.

Burnisher A cylindrical tool with integral collars that increase in diameter from one end of the tool to the other.

Burr A featheredge of metal left on a part being cut with a file or other cutting tool.

Bushing A sleeve placed in a bore to serve as a bearing surface.

Butane One form of liquefied petroleum gas, which see.

Butterfly The choke or throttle valve.

Bypass filter Type of oil filter in which only some of the oil from the oil pump flows through the filter. The remainder of the oil bypasses the filter on its way to engine parts.

Caliper A measuring tool that can be set to measure the thickness of a block, diameter of a shaft, or bore of a hole (inside caliper).

Cam An irregularly shaped moving part designed to move or alter the motion of another part.

Cam ground Refers to oval-shaped piston, so ground as to permit piston to expand and assume a round shape when hot.

Camshaft The shaft in the engine which has a series of cams for operating the valve mechanisms. It is driven by gears or sprockets and chain from the crankshaft.

Carbon A substance deposited on engine parts by the combustion of the fuel. Carbon forms on pistons, rings, valves, etc., inhibiting their action.

Carbon dioxide A gas resulting from burning of fuel.

Carbon monoxide A poisonous gas produced by a running gasoline engine.

Carburetion The actions that take place in the carburetor: converting liquid fuel to vapor and mixing it with air to form a combustible mixture.

Carburetor The device in the fuel system which mixes air and gasoline (vaporizing the gasoline as it does so) in varying proportions to suit engine operating conditions.

Cetane Ignition quality of diesel fuel. A high-cetane fuel ignites more easily (at lower temperature) than a low-cetane fuel.

CFR Uniontown road test A road test used to establish octane rating of different fuels.

Change of state Changing of a substance from solid to liquid, or from liquid to vapor, or vice versa.

Chassis The assembly of mechanisms that make up the major operating part of the vehicle. It is usually assumed to include everything except the car body.

Choke In the carburetor, a device that chokes off the air flow through the air horn, producing a partial vacuum in the air horn for greater fuel delivery and a richer mixture.

Clearance The space between two moving parts or between a moving and a stationary part, such as a journal and a bearing. Clearance is considered to be filled with lubricating oil when engine is running.

Coil spring A spring made up of an elastic metal, such as steel, formed into a wire or bar and wound into a coil.

Combination fuel pump A fuel pump with which a vacuum pump for operating the windshield wipers has been combined.

Combustion In the engine, the rapid burning of air-fuel mixture in cylinder.

Combustion chamber The space at the top of the cylinder and in the head in which combustion of the air-fuel mixture takes place.

Compensating circuit A special circuit in some carburetors to compensate for variations in fuel discharge from main nozzle. Compensating-circuit fuel nozzle discharges more fuel when nozzle discharges less, and vice versa, so that a balanced air-fuel mixture is delivered at all times.

Compression gauge A device for testing the amount of pressure developed in the engine cylinder during cranking.

Compression ratio The ratio between the volume in the cylinder with the piston at BDC and the volume with the piston at TDC.

Compression rings The upper ring or rings on a piston, designed to hold the compression in the cylinder and prevent blow-by.

Compression stroke The piston stroke from BDC to TDC during which both valves are closed and the air-fuel mixture is compressed.

Condensation The changing of a vapor to a liquid due to temperature, pressure, or other changes.

Connecting rods In the engine, linkages between the cranks on the crankshaft and the pistons.

Cooling system In the engine, the system that removes heat from the engine and thereby prevents overheating. It includes water jackets, water pump, radiator, and thermostat.

Crank A device for converting reciprocating motion into rotary motion, or vice versa.

Crankcase The lower part of the engine, in which the crankcase rotates. The upper part of the crankcase is lower section of the cylinder block, while the lower part is made up of the oil pan.

Crankcase dilution Dilution of the lubricating oil in the oil pan by the seepage of liquid gasoline down the cylinder walls.

Crankcase ventilator The device that permits air to flow through engine crankcase when engine is running.

Crankpin The bearing surface on a crank of the crankshaft, to which the connecting rod is attached.

Crankshaft *The main rotating member, or shaft, of the engine, with* cranks to which the connecting rods are attached.

Cycle In the engine, the four piston strokes (or two piston strokes) that complete the working process and produce power.

Cylinder In the engine, the tubular opening in which the piston moves up and down.

Cylinder block The basic framework of the engine in and on which the other engine parts are attached. It includes the engine cylinders and the upper part of the crankcase.

Cylinder head The part of the engine that encloses the cylinder bores. Contains water jackets and, on I-head engine, the valves.

Degree 1/360 part of a circle.

Detergent A chemical sometimes added to the engine oil, designed to help keep the internal parts of the engine clean by preventing the accumulation of deposits.

Detonation In the engine, excessively rapid burning of the compressed charge which results in *knock*, which see.

DG oil Lubricating oil for average, or normal, diesel-engine service.

Dial indicator A gauge that has a dial face and needle to register movement. Used to measure variations in size, movements too small to be measured conveniently by other means, etc.

Diaphragm A flexible membrane, in automotive components usually made of fabric and rubber, clamped at the edges, and usually spring-loaded; used in fuel pump, vacuum pump, distributor, etc.

Diesel cycle An engine cycle of events in which air alone is compressed and fuel oil injected at the end of the compression stroke. The heat produced by compressing the air ignites the fuel oil.

Dip stick The oil-level indicator stick.

Downdraft carburetor A carburetor in which the air horn is so arranged that the air passes down through it on its way to the intake manifold.

Drill Also called *twist drill.* A cylindrical bar with helical grooves and a point, for cutting holes in material. Also refers to the device that rotates the drill.

Dry friction The friction between two dry solids.

DS oil Lubricating oil for severe, or heavy-duty, diesel-engine service.

Dual carburetors Carburetors with two air horns, fuel nozzles, throttle valves, idle circuits, etc.

Dynamometer A device for measuring power output of an engine.

Eccentric Off center.

Economizer valve The mechanism in the carburetor that permits a rich mixture for full-load engine operation but leans the mixture for more economical operation on part throttle.

Efficiency Ratio between the effect produced and the energy expended.

Electric system In the automobile, the system that electrically cranks the engine for starting, furnishes high-voltage sparks to the engine cylinders to fire the compressed air-fuel charges, lights the lights, operates the heater motor, radio, etc. Consists, in part, of starting motor, wiring, battery, generator, regulator, ignition distributor, ignition coil.

Energy Energy is the capacity or ability to do work.

Engine The assembly that burns fuel to produce power, sometimes referred to as the power plant.

Engine tune-up The procedure of checking and adjusting various engine components so that engine is restored to top operating condition.

Ethyl Tetraethyllead, which see.

Evaporation The change of a liquid to a vapor, or gas.

Exhaust-gas analyzer A device for analyzing exhaust gases to determine carburetor action.

Exhaust manifold The part of the engine that provides a series of passages through which burned gases from the engine cylinders can flow.

Exhaust muffler The device in the exhaust line that muffles the sound of exhaust.

Exhaust stroke The piston stroke from BDC to TDC during which the exhaust valve is open so that the burned gases are forced from the cylinder.

Exhaust valve The valve that opens to allow the burned gases to exhaust from the engine cylinder during the exhaust stroke.

Expansion plug A plug that is slightly dished out. When driven into place, it is flattened and expanded to fit tightly.

Extreme-pressure lubricant A special lubricant for use in hypoid-gear differentials.

Fan The device on the front of the engine that rotates to draw a blast of cooling air through the radiator.

Fast idle The mechanism on the carburetor that holds the throttle valve slightly open when the engine is cold so that the engine will idle at a higher rpm when cold.

Feeler stock Strips of metal of accurately known thickness, used to measure clearances.

File A cutting tool with a large number of cutting edges arranged along a surface.

Filter That part in the lubricating or fuel system through which fuel, air, or oil must pass so that dust or dirt is removed.

Firing order The order in which the engine cylinders fire, or deliver, their power strokes.

Float bowl In the carburetor, the reservoir from which gasoline feeds into the passing air.

Float circuit The circuit in the carburetor that controls entry of fuel and fuel level in the float bowl.

Float level The float position at which the needle valve closes the fuel inlet to the carburetor to prevent further delivery of fuel.

Flywheel The rotating metal wheel, attached to the crankshaft, that helps even out the power surges from the power strokes and also serves as part of the clutch and engine-cranking system.

Four-barrel carburetor A carburetor with four air horns. In effect, two two-barrel, or dual, carburetors in a single assembly. Used on several V-8 engines.

Four cycle Short for four-stroke cycle, which see.

Four-stroke cycle The four operations of intake, compression, power, and exhaust, or four piston strokes, that make up the complete cycle of events in the four-stroke-cycle engine.

Friction The resistance to motion between two bodies in contact with each other.

Friction bearing Type of bearing in which moving parts are in sliding contact; sleeve, guide, or thrust bearing.

Fuel gauge The gauge that indicates to the driver the height of the fuel level in the fuel tank.

Fuel injector A device in a diesel-engine fuel system for injecting fuel oil into the cylinder.

Fuel jet See *jet*.

Fuel line The pipe or tube through which fuel travels from the tank to the fuel pump and from the pump to the carburetor.

Fuel nozzle The tube in the carburetor through which gasoline feeds from the float bowl to the passing air.

Fuel system In the automobile, the system that delivers to the engine cylinders the combustible mixture of vaporized fuel and air. It consists of fuel tank, lines, gauge, carburetor, manifold.

Fuel tank The metal tank that serves as a storage place for gasoline.

Full-flow filter Type of oil filter in which all the oil from the oil pump flows through the filter.

Full throttle Wide-open throttle position with accelerator pressed all the way down to floor board.

Gasket A flat strip, of cork or other material, placed between two surfaces to provide a tight seal between them.

Gasket cement An adhesive material used to apply gaskets.

Gasoline A hydrocarbon suitable as an engine fuel, obtained from petroleum.

Gear lubricant A type of grease or oil designed especially to lubricate gears.

Gear-type pump A pump using a pair of matching gears that rotate; meshing of the gears forces oil (or other liquid) from between the teeth through the pump outlet.

Generator The part of the electric system that converts mechanical energy into electric energy for lighting lights, charging the battery, operating the ignition system, etc.

Goggles Special glasses worn over the eyes to protect them from flying chips, dirt, or dust.

Governor A device, often installed under the carburetor, that prevents engine speed from exceeding a preset maximum.

Gravity The attractive force between objects that tends to bring them together. A stone dropped from the hand falls to the earth because of gravity.

Grease Lubricating oil to which thickening agents have been added.

Greasy friction The friction between two solids coated with a thin film of oil.

Grinding wheel An abrasive wheel used for grinding metal objects held against it.

Heat-control valve In the engine, a thermostatically operated valve in the exhaust manifold for varying heat to intake manifold with engine temperature.

Heat of compression Increase of temperature brought about by compression.

Heptane A reference fuel that knocks very easily, used in various proportions with iso-octane for comparative test of knock characteristics of fuels.

High compression A term used to refer to the increased compressions of modern automotive engines.

High-speed circuit The circuit in the carburetor that supplies fuel to the air passing through the air horn during medium- and high-speed, part- to full-throttle operation.

High-test gasoline A term referring to the octane rating of a fuel. A high-test fuel has a high octane rating.

Hone An abrasive stone that is rotated in a bore or bushing to remove material.

Horsepower A horsepower is a measure of a definite quantity of power; 33,000 ft-lb of work per minute.

Hydrocarbon A compound made of the elements hydrogen and carbon; gasoline is a hydrocarbon.

Hydrometer A device to determine the specific gravity (roughly the heaviness) of a liquid. This determination indicates the freezing point of the coolant in the cooling system, for example.

Idle circuit In the carburetor, the passage through which fuel is fed when the engine is idling.

Idle mixture The air-fuel mixture supplied to the engine during idle.

Idle-mixture adjustment screw The adjustment screw that can be turned in or out to lean or enrich the idle mixture.

Idle port The opening into the air horn through which the idle circuit in the carburetor discharges.

Idling speed The speed at which the engine runs without load when the accelerator pedal is released.

Ignition coil That part of the ignition system which acts as a transformer to step up the battery voltage to many thousands of volts; the high-voltage surge then produces a spark at the spark-plug gap.

Ignition distributor That part of the ignition system which closes and opens the circuit to the ignition coil with correct timing and distributes to the proper spark plugs the resulting high-voltage surges from the ignition coil.

Ignition system In the automobile, the system that furnishes high-voltage sparks to the engine cylinders to fire the compressed air-fuel charges. Consists of battery, ignition coil, ignition distributor, ignition switch, wiring, spark plugs.

Indicated horsepower A measurement of engine power based on power actually developed in the engine cylinders.

Inertia Property of objects that causes them to resist any change in speed or direction of travel.

Intake manifold The part of the engine that provides a series of passages from the carburetor to the engine cylinders through which air-fuel mixture can flow.

Intake stroke The piston stroke from TDC to BDC during which the intake valve is open and the cylinder receives a charge of air-fuel mixture.

Intake valve The valve that opens to permit air-fuel mixture to enter the cylinder on the intake stroke.

Iso-octane A reference fuel that shows great resistance to knocking, used in various proportions with heptane for comparative test of knock characteristics of various fuels.

Jackets The water jackets that surround the cylinders, through which the cooling water passes.

Jet A fuel nozzle or calibrated fuel passage in the carburetor.

Knock In the engine, a rapping or hammering noise resulting from excessively rapid burning of the compressed charge.

Liquefied petroleum gas A hydrocarbon suitable as an engine fuel obtained from petroleum and natural gas, a vapor at atmospheric pressure but liquefied if put under sufficient pressure.

Lock nut A second nut turned down on a holding nut to prevent loosening.

Low-speed circuit The circuit in the carburetor that supplies fuel to the air passing through the air horn during low-speed, part-throttle operation.

LPG Liquefied petroleum gas, which see.

Lubrication system The system in the engine that supplies moving engine parts with lubricating oil.

Main fuel nozzle The fuel nozzle in the carburetor that supplies fuel when the throttle is partially to fully open.

Manifold The intake or exhaust manifold, which see.

Manifold vacuum The vacuum in the intake manifold that develops as a result of the vacuum in the cylinders on their intake strokes.

Mechanical efficiency In an engine, the ratio between brake horsepower and indicated horsepower.

Mechanical octane Octane needs of an engine, resulting from the mechanical design, or shape and relation of parts.

Mechanism A system of interrelated parts that make up a working agency.

Metering rod A device in the carburetor that enlarges or decreases the fuel passage to the fuel nozzle, varying fuel delivery for various throttle openings.

Micrometer A measuring device that measures accurately such dimensions as shaft or bore diameter or thickness of an object.

Mike A slang term for micrometer, which see.

Missing In the engine, the failure of a cylinder to fire when it should.

ML oil Oil for light automotive service.

MM oil Oil for medium, or average, automotive service.

MS oil Oil for severe automotive service.

Muffler In the exhaust, a device, through which the exhaust gases must pass, that muffles the sound.

Nozzle Fuel nozzle, or jet, through which fuel passes when it is discharged into the carburetor air horn.

Octane A measure of antiknock value of engine fuel.

Oil cleaner The filtering device through which oil passes, which filters dirt and dust from the oil.

Oil-control rings The lower ring or rings on a piston designed to prevent excessive amounts of oil from working up into the combustion chamber.

Oil dilution Dilution of oil in the crankcase, caused by leakage of liquid gasoline from the combustion chamber past the pistons.

Oil filter That part of the lubricating system that removes dirt and dust from the oil circulated through it.

Oil-level indicator The indicator, usually a "stick," that can be removed to determine the level of oil in the crankcase.

Oil pan The detachable lower part of the engine, usually made of sheet metal, that encloses the crankcase and acts as an oil reservoir.

Oil-pressure indicator Oil gauge that reports to the driver the oil pressure in the engine lubricating system.

Oil pump In the lubrication system, the device that delivers oil from the oil pan to the various moving engine parts.

Oil pumping Passing of oil past the piston rings into the combustion chamber because of defective rings, piston, worn cylinder walls, etc.

Oil seal A seal placed around a rotating shaft, etc., to prevent escape of oil.

Oilstone A block of abrasive material bonded together, used for removing metal.

Orifice A small opening, or hole, into a cavity.

Otto cycle The four operations of intake, compression, power, and exhaust; so named for the inventor of the four-stroke cycle engine, Dr. Nikolaus Otto.

Petroleum The crude oil extracted from the ground from which gasoline, lubricating oil, and other products are refined.

Ping A metallic rapping sound from engine cylinder, caused by detonation.

Piston In the engine, the cylindrical part that moves up and down in the cylinder.

Piston pin Also called *wrist pin*. The cylindrical, or tubular, metal object that attaches the piston to the connecting rod.

Piston-pin bearings The bearings or bushings in the piston and upper end of the connecting rod, in which the piston pin rides.

Piston rings The rings fitted into grooves in the piston. There are two types, compression rings (for sealing the compression into the combustion chamber) and oil rings (to scrape excessive oil off the cylinder walls and thereby prevent it from working up into and burning in the combustion chamber).

Piston skirt The lower part of the piston.

Piston slap Hollow, muffled, bell-like sound made by excessively loose piston slapping cylinder wall.

Poppet valve A mushroom-shaped valve, widely used in automotive engines.

Port In the carburetor, an opening or jet through which fuel is discharged into the air horn.

Power The rate of doing work.

Power jet The fuel nozzle that discharges additional fuel into the high-speed circuit of the carburetor when the throttle is opened wide.

Power piston The vacuum-operated piston in carburetors that releases at wide-open throttle to permit delivery of a richer air-fuel mixture.

Power stroke The piston stroke from TDC to BDC during which the air-fuel mixture burns and forces the piston down, so that the engine produces power.

Power train The group of mechanisms that carries the rotary motion developed in the engine to the car wheels; it includes clutch, transmission, propeller shaft, differential, and axles.

Preignition Ignition of the air-fuel mixture in the engine cylinder (by any means) before the ignition spark occurs at the spark plug.

Press fit A fit so tight, as a piston pin in a pin bushing, for example, that the pin has to be pressed into place (usually with an arbor press).

Pressure cap The type of radiator cap used with pressure cooling systems; it contains a pressure relief valve and a vacuum valve.

Pressure-feed A type of engine lubricating system that makes use of an oil pump to force oil through tubes and passages to the various engine parts requiring lubrication.

Pressure regulator The device in an LPG fuel system that reduces the pressure on the LPG, permitting the fuel to vaporize in readiness for mixing with air in the carburetor.

Pressure relief valve A valve in the oil line that opens to relieve excessive pressures that the oil pump might develop.

Prony brake A device for measuring power output of an engine (brake horsepower).

Propane One type of LPG, which see.

Psi Pounds per square inch; usually used to indicate pressure of a liquid or gas.

Puller Generally, a service tool that permits removal of one part from another without damage. Contains a screw or screws that can be turned to apply gradual pressure.

Quadrijet carburetor Four-barrel carburetor, which see.

Radiator In the cooling system, the device that removes heat from water passing through it; it takes hot water from the engine and returns cooled water to the engine.

Radiator cap The cap placed on the radiator filler tube.

Ribbon-cellular radiator core One type of radiator core consisting of ribbons of metal soldered together along their edges.

Rocker arm A part in the fuel pump, linked to the diaphragm, that rocks back and forth as its end rides on a cam on the camshaft.

Rotor pump A type of pump using a pair of rotors, one inside the other, to produce the oil pressure required to circulate oil to engine parts.

Rpm Revolutions per minute.

Scored Scratched or grooved, as a cylinder wall may be scored by abrasive particles moved up and down by the piston rings.

Scraper A device used in engine service to scrape carbon, etc., from engine block, pistons, etc.

Screen A fine-mesh screen in the fuel line that prevents the passage of dirt or dust into the carburetor.

Shim A strip of copper or similar material used, for example, under a bearing cap to increase bearing clearance.

Sludge Accumulation in oil pan, containing water, dirt, and oil; sludge is very viscous and tends to prevent lubrication.

Soldering The uniting of pieces of metal with solder, flux, and heat.

Spark plug The assembly, which includes a pair of electrodes and an insulator, that has the purpose of providing a spark gap in the engine cylinder.

Splash-feed A type of engine lubricating system that depends on splashing of the oil for lubrication to moving engine parts.

Spring An elastic device that yields under stress or pressure but returns to its original state or position when the stress or pressure is removed.

Storage battery The part of the electric system which acts as a reservoir for electric energy, storing it in chemical form.

Stroke In an engine, the distance that the piston moves from BDC to TDC.

Stud A headless bolt threaded on both ends.

Tachometer A device for measuring engine speed, or rpm.

Tank unit The unit of the fuel-indicating system that is mounted in the fuel tank.

Tap A special cutting tool for cutting threads in a hole.

Taper A decrease in diameter from one to another place as taper in a cylinder, taper of a shaft.

TDC Top dead center, which see.

Tel Tetraethyllead, which see.

Temperature indicator A gauge that indicates to the driver the temperature of the coolant in the cooling system, thus giving warning of impending damage if the temperature goes too high.

Tetraethyllead A chemical put into engine fuel which increases octane rating, or reduces knock tendency.

Thermal efficiency Relationship between the power output and the energy in the fuel burned to produce the output.

Thermostat A device that operates on temperature changes. Several thermostats are used in engines. There is one in the cooling system, another in the manifold heat control, etc.

Thermosiphon cooling Cooling by natural circulation of water, resulting from fact that a given volume of hot water is lighter than an identical volume of cold water.

Throttle cracker Linkage from the starting motor switch to the throttle, which opens the throttle slightly when the engine is being cranked.

Throttle-return check A device on the carburetor that prevents excessively sudden closing of the throttle.

Throttle valve The round disk in the lower part of the carburetor air horn that can be turned to admit more or less air.

Timing In the engine, refers to timing of valves and also timing of ignition.

Top dead center The piston position at which the piston has moved to the top of the cylinder and the center line of the connecting rod is parallel to the cylinder walls.

Torque Turning or twisting effort, measured in pound-feet.

Torque wrench A special wrench with a dial that indicates the amount of torque being applied to a nut or bolt.

Trouble-shooting The detective work necessary to run down the cause of a trouble; implies the correction of the trouble by elimination of cause.

Tube-and-fin radiator core One type of radiator core, consisting of tubes to which cooling fins are attached; water flows through the tubes between the upper and lower radiator tanks.

Turbulence In the engine, the rapid swirling motion imparted to the air-fuel mixture entering the cylinder.

Two-barrel carburetor A dual carburetor, which see.

Two cycle Short for two-stroke cycle, which see.

Two-stroke cycle The series of events taking place in a two-stroke-cycle engine, which are intake, compression, power, and exhaust, all of which take place in two piston strokes.

Unbalanced carburetor Carburetor in which the float bowl is vented into the open air, as opposed to a *balanced carburetor,* which see.

Updraft carburetor Carburetor in which air horn and other parts are so arranged that the air passes up through the air horn on its way to the intake manifold. Used on engines where there is not enough headroom for a downdraft carburetor.

Vacuum An absence of air or other substance.

Vacuum gauge In automotive-engine service, a device that measures intake-manifold vacuum and thereby indicates actions of engine components.

Valve A device that can be opened or closed to allow or stop the flow of a liquid, gas, or vapor from one place to another.

Valve clearance The clearance between the adjusting screw on the valve lifter and the valve stem (in L-head engines) or between the rocker arm and the valve stem (in I-head engines).

Valve lifter Also called *valve tappet.* The cylindrical part of the engine that rests on a cam of the camshaft and is lifted by the cam action so that the valve is opened. There is a valve lifter for each valve.

Vapor lock A condition in the fuel system, in which gasoline has vaporized, as in the fuel line, so that fuel delivery to the carburetor is blocked or retarded.

Vent An opening from an enclosed chamber, through which air can pass.

Venturi In the carburetor, the constriction in the air horn that produces the vacuum responsible for the movement of gasoline into the passing air.

Vibration A complete rapid motion back and forth; oscillation.

Viscosity The term used to describe a liquid's resistance to flow. A thick oil has greater viscosity than a thin oil.

Viscous Thick, tending to resist flowing.

Viscous friction Friction between layers of a liquid.

Vise A gripping device for holding a piece while it is being worked on.

Volatility A measurement of the ease with which a liquid vaporizes.

Volumetric efficiency Ratio between amount of air-fuel mixture that actually enters an engine cylinder to the amount that could enter under ideal conditions.

Water-distributing tube In the engine cooling system, a tube that improves water circulation around exhaust valves and other areas that might overheat.

Water jacket The space between the inner and outer shells of the cylinder block or head, through which cooling water can circulate.

Water pump In the cooling system, the device that maintains circulation of the water between the engine water jackets and the radiator.

Water sludge A black, viscous substance that forms in the engine crankcase due to water's collecting and being whipped into the oil by the crankshaft.

Work Work is the changing of the position of a body against an opposing force, measured in foot-pounds.

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